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WAYNE KERR

Instruction/Service Manual
for

6425
PRECISION COMPONENT ANALYSER

Part No. 9H6425

FARNELL INSTRUMENTS LIMITED, SANDBECK WAY, WETHERBY, WEST YORKSHIRE LS22 4DH
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6425 PRECISION COMPONENT ANALYSER

THIS MANUAL COMPRISES TWO PARTS
WHICH ARE INDEPENDENTLY INDEXED

PART 1 OPERATING INSTRUCTIONS

PART 2 SERVICE/MAINTENANCE

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Precision Component Analyser

OPERATING INSTRUCTIONS

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Frontispiece Precision Component Analyzer

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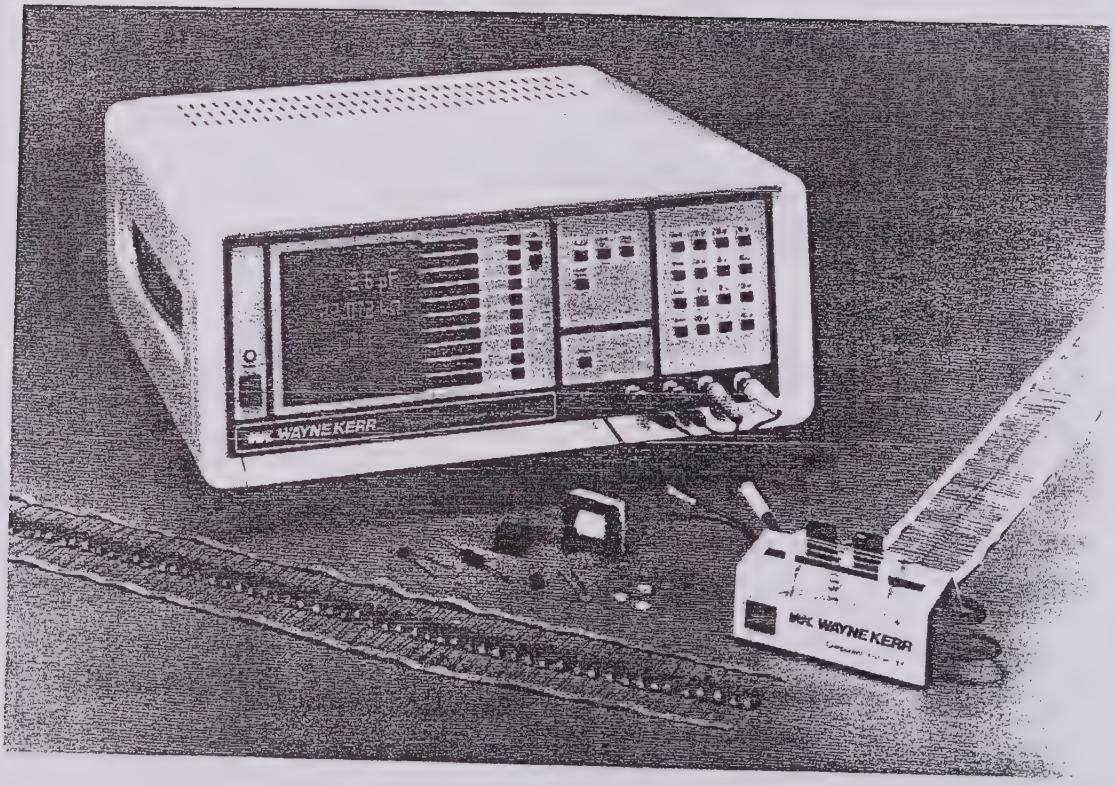
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1 INTRODUCTION

The 6425 is designed to give fast and accurate readout of component values, easy sorting of resistors, capacitors and inductors, detailed analysis of networks, and rapid monitoring of changing values. An extended measurement range, wide choice of operating frequency and adjustable drive level make the Analyzer a powerful tool in design laboratories, goods inwards sections, test departments and in connection with chemical and physical research work.

A cathode-ray tube is used to present clear and unambiguous results in numeric and graphic form, to display warning and other messages and, under software control, it automatically labels a set of ten 'soft' keys to show the parameter selection available for each mode of operation. All key settings are retained in non-volatile memory. Because there are no variable controls requiring user adjustment, and values can be read directly in the terms required, confidence in the validity of results is maximized for all levels of operator skill.

Four-terminal connections provide continuous correction for losses occurring in measurement leads or fixtures, ensuring the maintenance of dependable five-figure resolution and the specified accuracy over the full C, L and R ranges. The number of digits displayed - up to a maximum of six - is automatically adjusted to be commensurate with the accuracy. Trimming (O/C and S/C) is, in each case, a simple push-button operation, with corrections applied automatically to suit the particular measurement conditions at any time.

Range selection is automatic, with manual over-ride provided, together with a visual reminder when an alternative range would offer better resolution. Should a measurement lie beyond the range selected manually, the display is blanked, obviating false results.

continued.....

Sorting, pass/fail and deviation operations are all provided for. A numeric keypad allows limits to be set precisely, in % or Absolute terms, with the software guiding the user through the procedure and warning of any missing or invalid keying operations. A keyboard lockout function protects against unauthorized or inadvertent changes to established measurement conditions.

Other features include direct readout of D,Q or loss resistance at the same time as C or L, choice of equivalent series or parallel circuit values, display of actual signal level at the test point and provision for introducing dc polarizing voltages.

Options for the Precision Component Analyzer include an RS232-C Printer Interface; a GPIB Interface (to IEEE Std 488-1978); a Standard Handler Interface and Analog Outputs of 2 measured parameters. Basic information on these options is included in this Manual : for further details please contact your Supplier.

2 SPECIFICATION

MEASUREMENT SYSTEM

Microprocessor-controlled.
'Soft' keys for measurement functions & conditions.
Selected functions held in non-volatile memory.
Electronic 'lock-out' of key functions.
Measurement trigger by remote contacts.
Plug-in options for interface with controllers/printers/plotters/sorters.

DISPLAY

7-inch (18cm) CRT for values, conditions, soft-key functions, instructions and warning messages.
Number of digits displayed (max: 6) depends on measurement accuracy.

MEASUREMENT FUNCTIONS

C & D, C & Q, C & R } Series or parallel
L & D, L & Q, L & R } equivalent circuit
C & G, L & G Parallel equivalent circuit
Z & ∠θ, Y & ∠θ Signal level at Unknown.

Deviation: % change from measured Nominal (L C Z or Y).
Limits: % or Absolute for Go/Nogo testing, with Analog Bar Display.
Binning: Sorts by major/minor term limits into 9 bins (tenth for rejects).
Auto-Trim: Compensates for residual series impedance and parallel capacitance of measurement leads up to 1 Ω /50pF maximum. Trimmed value held in non-volatile store.

MEASUREMENT CONDITIONS

Frequency (Hz): 20, 25, 30, 40, 50, 60, 80, 100, 120, 150, 200 etc, repeats each decade up to 60k, then 75k, 100k, 120k, 150k, 200k, 300k (42 frequencies).
Frequency accuracy: ±0.01%.

continued...

MEASUREMENT CONDITIONS (continued)

AC Drive level:

10mV - 500mV (10mV steps) } Available if Unknown
520mV - 1.0V (20mV steps) } impedance > 10Ω
1.05V - 2.5V (0.05V steps) } Available if Unknown
2.6V - 5.0V (0.1V steps) } impedance > 80Ω
1mA - 50mA (1mA steps) } Available if Unknown
52mA - 100mA (2mA steps) } impedance < 10Ω

Drive mode (current/voltage) selected automatically as a function of impedance range.

When in current drive, with Z or Y selected, the voltage across the Unknown can be displayed, and vice versa.

At 300kHz, voltage drive restricted to 3V maximum.

AC Level accuracy (at source):

30Hz - 120kHz: voltage ±4% ±2mV
" " current ±5% ±200μA

20Hz & 25Hz } voltage ±7.5% ±2mV
120kHz - 200kHz } current ±8.5% ±200μA

300kHz: voltage ±11.5% ±2mV
" current ±12.5% ±200μA

Source loading. Max level reduction at Zu = 10Ω:

Capacitive or Inductive Unknown:
4% (voltage drive)
3% (current drive)

Resistive Unknown:
18% (voltage or current drive).

DC Bias voltage.

Internal: adjustable supply with separate on/off switch and safety link.
0.1V - 5V (0.1V steps)
5.2V - 10V (0.2V steps)
10.5V - 20V (0.5V steps)
Open- circuit accuracy ±2% ±60mV
Max. continuous leakage current in Unknown: 3mA +0.25mA/V.
Charge/discharge limited to <1A or <500V/sec.

DC Bias voltage (continued)

External: additional supply can be connected in series with internal supply to increase available voltage. Controlled by internal on/off switch. Supply current limited to 1A.

Max. total voltage (internal + external): 50V.

Open-circuit accuracy at measurement terminals: ±2% ±60mV.

Max. continuous leakage current in Unknown: 3mA.

MEASUREMENT RANGES

Automatic range selection can be inhibited by Hold function (Range Error shows when a change of range could give improved accuracy). When in Hold, a desired range can be selected by keying the corresponding code.

Range Number	Impedance coverage	Maximum ac Drive Level
1	< 1.25Ω	100mA
2	< 10Ω	100mA
3	> 10Ω	1V
4	> 80Ω	5V
5	> 640Ω	5V
6	> 5.12kΩ	5V
7	> 41kΩ	5V
8	> 328kΩ	5V

Range 8 available up to 10kHz.

Range 7 available up to 60kHz.

For drive levels below 25mA, Range 1 not available.

For drive levels below 250mV, highest range at each frequency not available.

At 300kHz, max level = 3V.

MEASUREMENT ACCURACY

At 1V or 100mA. Slow Speed. (See also page 2-7).
Resolution figures apply from 250mV or 25mA upwards. From 30mV to 240mV, and 3mA to 24mA, multiply by 10.

Resistance (R)

Basic accuracy (1kHz): ±.05% 0.2Ω - 12MΩ
Full details on pages 2-8 and 2-9.
Resolution: 0.005mΩ up to 10kHz
0.05mΩ at 100kHz
0.2mΩ at 300kHz

Conductance (G)

Basic accuracy (1kHz): ±.05% 80nS - 5S
Full details on pages 2-8 and 2-9.
Resolution: 0.01nS up to 10kHz
0.2nS at 20kHz
1nS at 50kHz
5nS at 100kHz
0.02μS at 300kHz

Capacitance (C)

Basic accuracy (1kHz): ±.05% 20pF - 1800μF
Full details on pages 2-10 and 2-11.
Resolution: 0.002pF at 1kHz
0.0002pF at 10kHz
0.002pF at 50kHz
0.01pF at 100kHz

Dissipation Factor (D)

Basic accuracy (1kHz): ±.0002 60pF - 320μF
Full details on pages 2-12 and 2-13.
Resolution: 0.00005 up to 10kHz
0.0005 at 100kHz
0.002 at 300kHz

Inductance (L)

Basic accuracy (1kHz): ±.1% 3μH - 200H
Full details on pages 2-14 and 2-15.
Resolution: 0.1nH from 5kHz upwards

Quality Factor (Q)

Basic accuracy (1kHz): ±(.05Q)% 40μH - 160H
Full details on pages 2-16 and 2-17.
Resolution:
better than 2% for Q ⟩ 1400 up to 10kHz
Q ⟩ 140 at 100kHz
Q ⟩ 32 at 300kHz

MEASUREMENT SELECTION	Repetitive (free-running) or Single shot triggered by dedicated front-panel key or remote contact via 3.5mm jack on front panel. This key remains active during keyboard lockout.
Measurement Speeds	Normal: Approx 400ms/measurement above 300Hz. Slows progressively below 300Hz to approx 600ms at 20Hz. Fast (reduced accuracy): Approx 125ms/measurement above 300Hz. Slows progressively below 300Hz to approx 600ms at 20Hz. Slow (improved resolution): Approx 1.3s/measurement up to 75kHz. 750ms/measurement for 100kHz and above.
MEASUREMENT CONNECTIONS	Four BNC connectors permit 2, 3 and 4-terminal connections with screens at ground potential. Connection diagrams available on CRT display. Terminals withstand connection of charged capacitors, up to 50V (100mF max) or up to 500V (2µF max), either polarity. Rear panel safety link can be removed to inhibit internal dc bias. External bias supply connects in place of safety link. Circuits are NOT protected against reverse-connected external supply.
TEMPERATURE RANGE	Storage: -40°C to +70°C (-40°F to +158°F). Operating: 0°C to +40°C (+32°F to +104°F). Full Accuracy: 10°C to +30°C (+50°F to +86°F).
POWER SUPPLY	115V ±10% or 230V ±10% ac only. Consumption nominally 70VA. Instruments may be converted for 50Hz or 60Hz operation by fitting an internal wire link. Operation is possible with this link incorrectly set, but full accuracy may not be maintained.

DIMENSIONS	Width:	443mm (17.5in.)
	Height (inc. feet):	195mm (7.7in.)
	Depth (overall):	470mm (18.5in.)
	Weight	16kg (35lb)

ACCESSORIES

1. Type 1305 or 1505: 4-terminal crocodile-clip leads.
2. Type 1405 or 1605: 4-terminal Kelvin clip leads.
3. Component Fixture type 1005, suitable for radial and axial components.

As standard, 6425 is supplied with accessory type 1605.

OPTIONS

RS232C Interface: provides automatic output of measurement data (e.g. to a printer).

GPIB Interface: provides either

i) automatic output of measurement data (e.g. to a printer), or

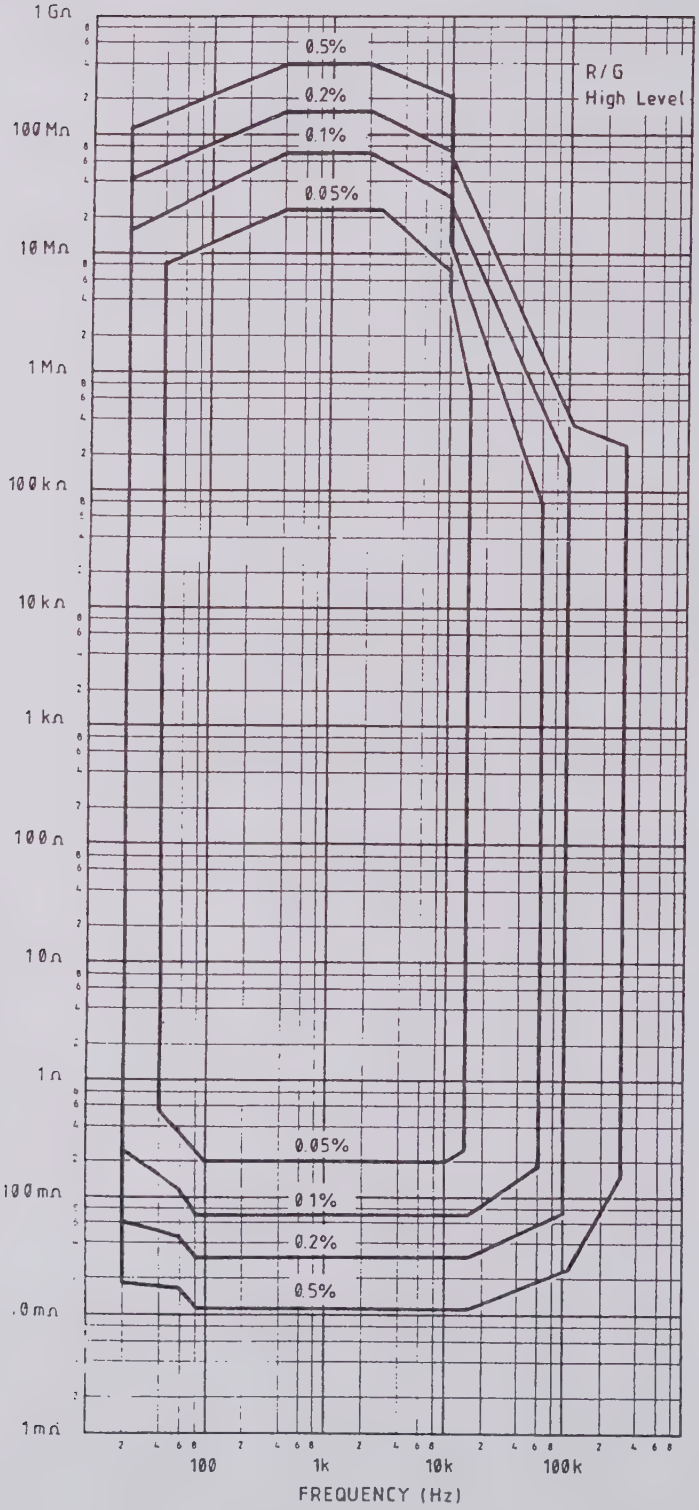
ii) full remote control of all functions via IEEE-488.

In step with rapidly developing technology the Company is continually improving its products and therefore reserves the right at any time to alter specifications or designs without prior notice.

MEASUREMENT ACCURACY

Iso-Accuracy charts define the measurement ranges available, at specified accuracies, over the available frequency band. For each of the five parameters - R/G, C, D, L and Q - two sets of curves are given: one for measurements at an ac level of 1V/100mA, the second for a level of 200mV/20mA. All curves assume that the Slow measurement speed is used, that the Analyzer has been trimmed at the frequency used for measurements and that the component under test is pure. Beside each chart is a summary of these conditions and information on the accuracy applicable when some or all of the conditions change.

R/G High Level Accuracy



CONDITIONS
AC Drive Level: 1V/100mA
Slow Speed
Analyzer trimmed at measurement frequency
$Q \nmid 0.1$

Except on highest and lowest measurement ranges, the adjacent Iso-Accuracy chart applies also as follows:

250mV - 5V and 25mA - 100mA
Normal Speed
Interpolated trim

For Fast Speed, on all ranges, the Normal Speed accuracy figures must be doubled. Supply frequency rejection is also reduced, causing additional unquantifiable errors dependent on measurement lead layout, particularly at frequencies below 600Hz and low a.c. drive levels.

O/C and S/C Trim corrections under various conditions of interpolation, speed and level are given in the table following these Iso-Accuracy charts.

For impure components, and for measurements on the highest or lowest available ranges, the full accuracy expressions, shown below, apply. During the first hour of operation, parallel capacitance trim may drift by up to 0.05pF, series impedance by up to 0.2mΩ. Subsequent drifts, including ambient temperature change not exceeding 5°C, are included in the interpolated trim correction figures in the table (page 2-18).

For $1 > Q > 0.1$ multiply accuracy by $(1+Q)$

For $Q > 1$ (loss resistance of inductor)
see Q accuracy chart (page 2-16)
$D < 1$ (loss resistance of capacitor)
see D accuracy chart (page 2-12)

High R values: Accuracy $= \pm(A + 100\ Y_T.Rx)\%$

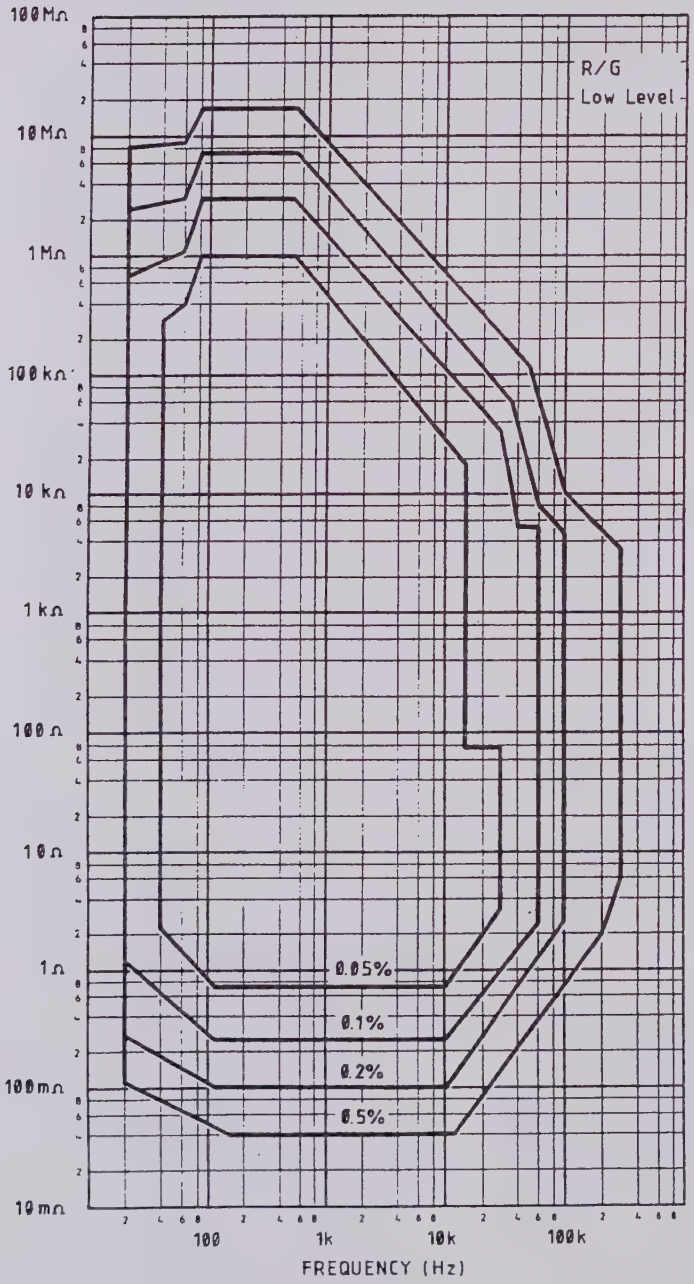
Low R values: Accuracy $= \pm(A + 100R_T/Rx)\%$

where
A = Accuracy from adjacent chart
Rx = measured value of unknown component
Y_T = sum of Y_I, Y_N, Y_L (as appropriate, from Table - page 2-18).

R_T = sum of Z_I, R_N, R_L (as appropriate, from Table - page 2-18).

Conductance (G): Find accuracy for equivalent R value from R = 1/G

R/G Low Level Accuracy



CONDITIONS
AC Drive Level: 200mV/20mA
Slow Speed
Analyzer trimmed at measurement frequency
$Q \leq 0.1$
Except on highest and lowest measurement ranges, the adjacent Iso-Accuracy chart applies also as follows:
50mV - 240mV and 5mA - 24mA
Normal Speed
Interpolated trim
For Fast Speed, on all ranges, the Normal Speed accuracy figures must be doubled. Supply frequency rejection is also reduced, causing additional unquantifiable errors dependent on measurement lead layout, particularly at frequencies below 600Hz and low a.c. drive levels.

O/C and S/C Trim corrections under various conditions of interpolation, speed and level are given in the table following these Iso-Accuracy charts.

For impure components, and for measurements on the highest or lowest available ranges, the full accuracy expressions, shown below, apply. During the first hour of operation, parallel capacitance trim may drift by up to 0.05pF, series impedance by up to 0.2mΩ. Subsequent drifts, including ambient temperature change not exceeding 5°C, are included in the interpolated trim correction figures in the table (page 2-18).

For $1 > Q > 0.1$ multiply accuracy by $(1+Q)$

For $Q > 1$ (loss resistance of inductor)
see Q accuracy chart (page 2-17)
$D < 1$ (loss resistance of capacitor)
see D accuracy chart (page 2-13)

High R values: Accuracy $= \pm (A + 100\ Y_T . Rx)\%$

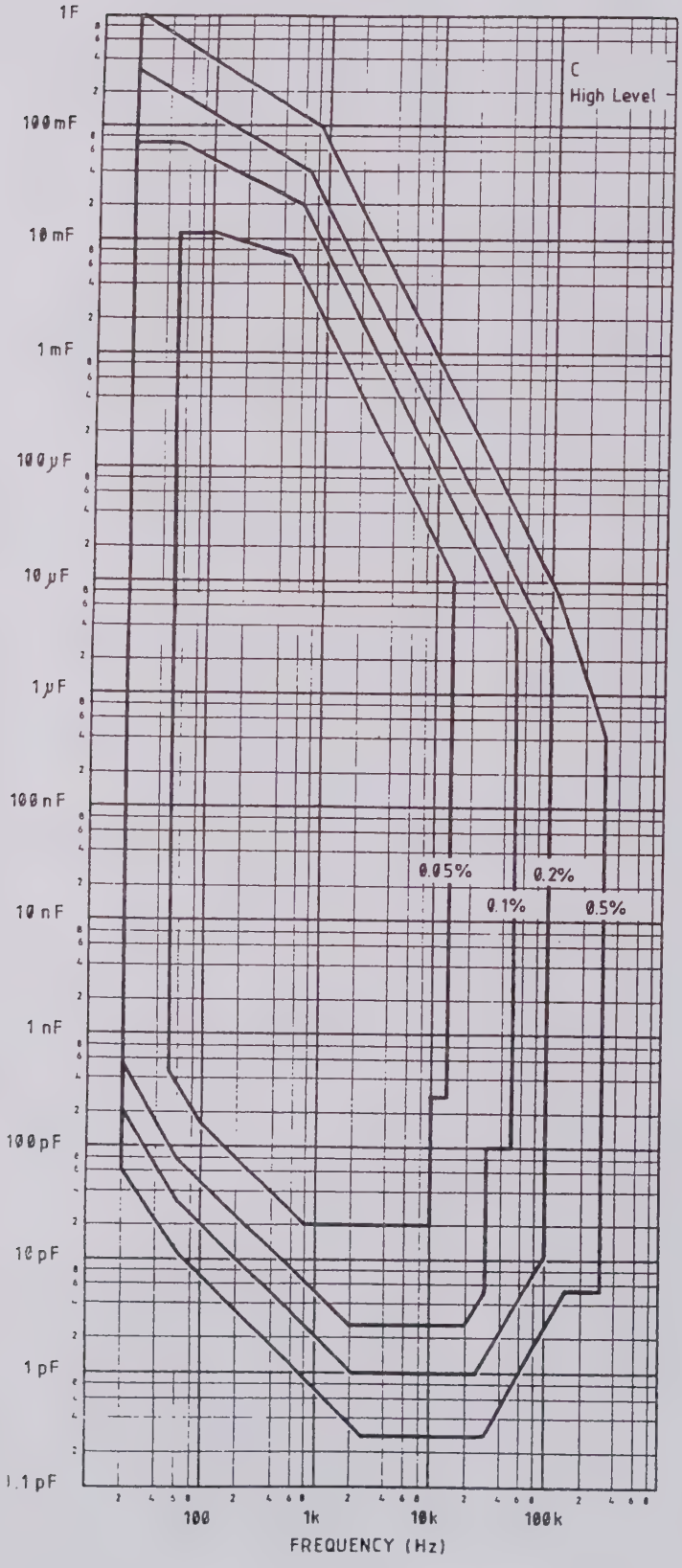
Low R values: Accuracy $= \pm (A + 100 R_T/Rx)\%$

where
A = Accuracy from adjacent chart
Rx = measured value of unknown component
Y_T = sum of Y_I, Y_N, Y_L (as appropriate, from Table - page 2-18).

R_T = sum of Z_I, R_N, R_L (as appropriate, from Table - page 2-18).

Conductance (G): Find accuracy for equivalent R value from R = 1/G

C High Level Accuracy



CONDITIONS
AC Drive Level: 1V/100mA
Slow Speed
Analyzer trimmed at measurement frequency
D ≤ 0.1
Except on highest and lowest measurement ranges, the adjacent Iso-Accuracy chart applies also as follows:
250mV - 5V and 25mA - 100mA
Normal Speed
Interpolated trim
For Fast Speed, on all ranges, the Normal Speed accuracy figures must be doubled. Supply frequency rejection is also reduced, causing additional unquantifiable errors dependent on measurement lead layout, particularly at frequencies below 600Hz and low a.c. drive levels.

O/C and S/C Trim corrections under various conditions of interpolation, speed and level are given in the table following these Iso-Accuracy charts.

For impure components, and for measurements on the highest or lowest available ranges, the full accuracy expressions, shown below, apply. During the first hour of operation, parallel capacitance trim may drift by up to 0.05pF, series impedance by up to 0.2m Ω. Subsequent drifts, including ambient temperature change not exceeding 5°C, are included in the interpolated trim correction figures in the table (page 2-18).
If D > 0.1, multiply C accuracy by (1 + D)
High C values: Accuracy = $\pm(A + 100X_T.\omega\, Cx)\%$

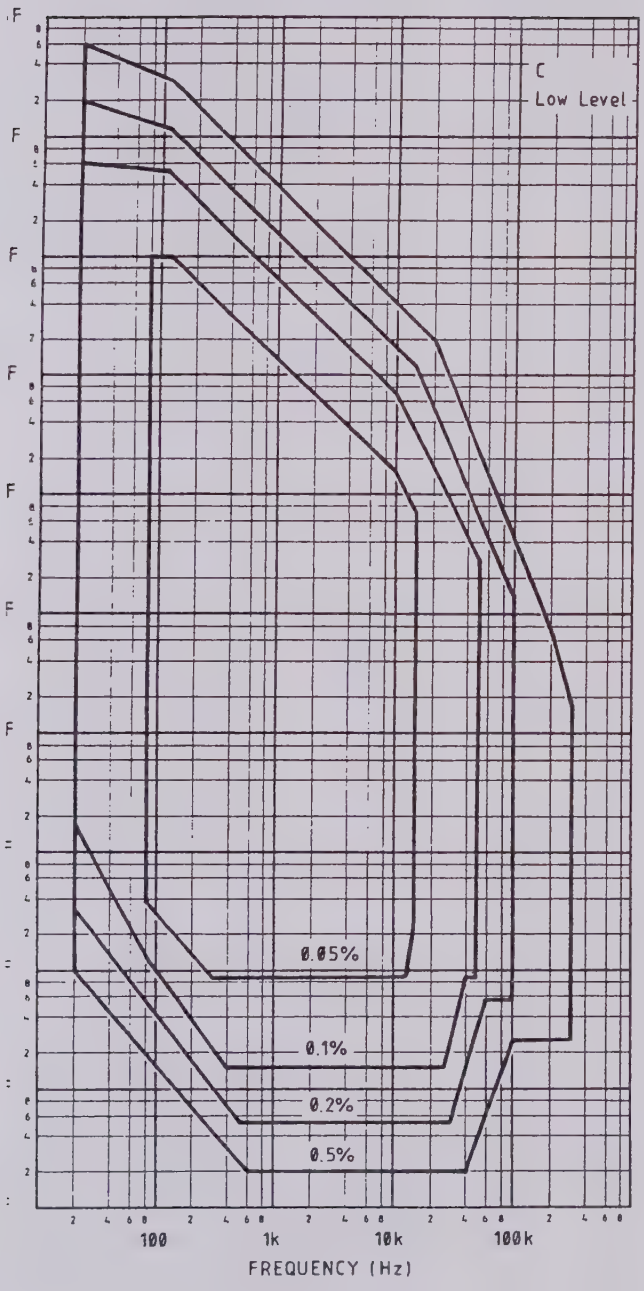
Low C values: Accuracy = $\pm(A + 100C_T/Cx)\%$

where
A = Accuracy from adjacent chart
Cx = measured value of unknown component
X_T = sum of Z_I, X_N, X_L (as appropriate, from Table - page 2-18).

C_T = sum of C_I, C_N, C_L (as appropriate, from Table - page 2-18).

ω = 2π x frequency

C Low Level Accuracy



CONDITIONS
AC Drive Level: 200mV/20mA
Slow Speed
Analyzer trimmed at measurement frequency
D ≤ 0.1
Except on highest and lowest measurement ranges, the adjacent Iso-Accuracy chart applies also as follows:

50mV - 240mV and 5mA - 24mA
Normal Speed
Interpolated trim

For Fast Speed, on all ranges, the Normal Speed accuracy figures must be doubled. Supply frequency rejection is also reduced, causing additional unquantifiable errors dependent on measurement lead layout, particularly at frequencies below 600Hz and low a.c. drive levels.

O/C and S/C Trim corrections under various conditions of interpolation, speed and level are given in the table following these Iso-Accuracy charts.

For impure components, and for measurements on the highest or lowest available ranges, the full accuracy expressions, shown below, apply. During the first hour of operation, parallel capacitance trim may drift by up to 0.05pF, series impedance by up to 0.2m Ω. Subsequent drifts, including ambient temperature change not exceeding 5°C, are included in the interpolated trim correction figures in the table (page 2-18).
If D > 0.1, multiply C accuracy by (1 + D)
High C values: Accuracy = $\pm(A + 100X_T.\omega\, Cx)\%$

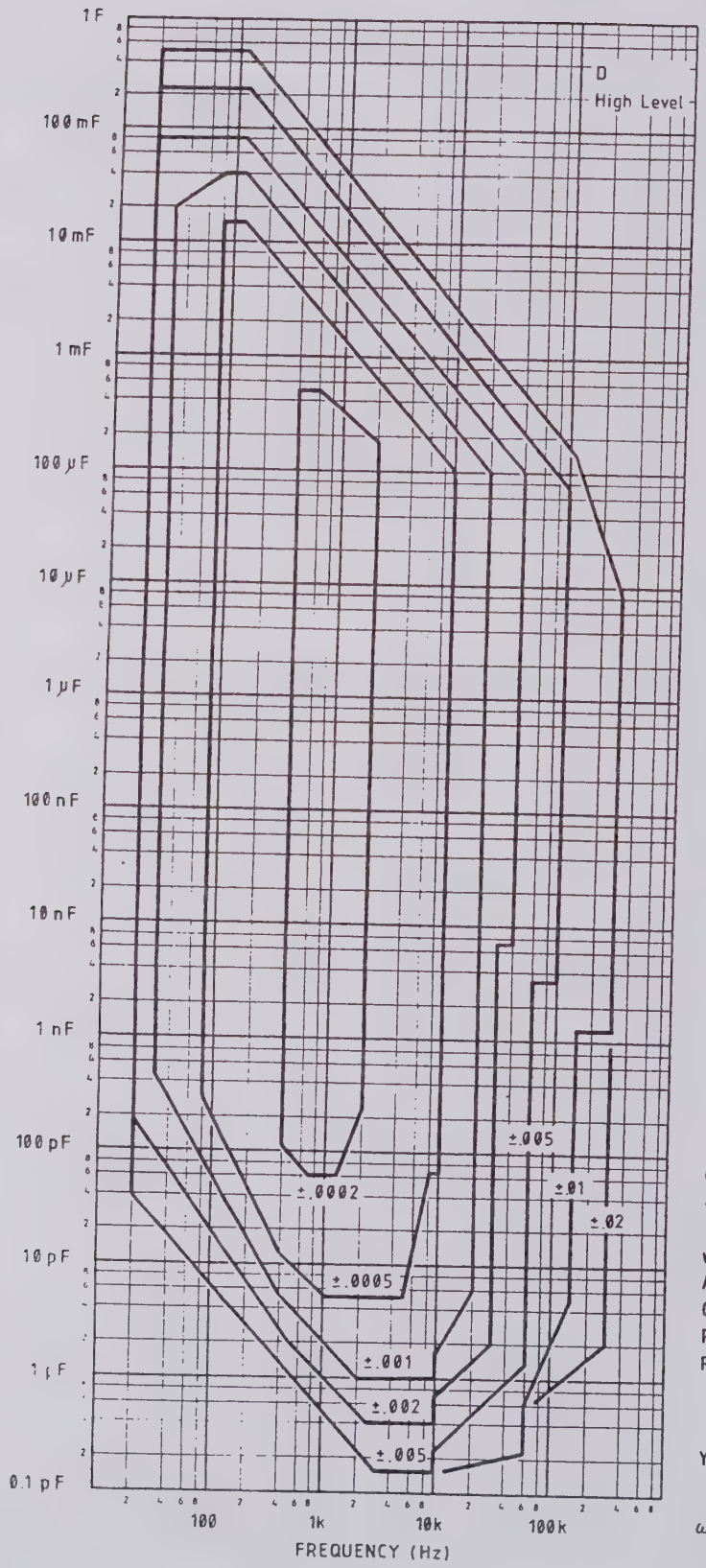
Low C values: Accuracy = $\pm(A + 100C_T/Cx)\%$

where
A = Accuracy from adjacent chart
Cx = measured value of unknown component
X_T = sum of Z_I, X_N, X_L (as appropriate, from Table - page 2-18).

C_T = sum of C_I, C_N, C_L (as appropriate, from Table - page 2-18).

ω = 2π x frequency

D High Level Accuracy



CONDITIONS
AC Drive Level: 1V/100mA
Slow Speed
Analyzer trimmed at measurement frequency
D ≤ 0.1
Except on highest and lowest measurement ranges, the adjacent Iso-Accuracy chart applies also as follows:
250mV - 5V and 25mA - 100mA
Normal Speed (not ± .0002 curve)
Interpolated trim
For Fast Speed, on all ranges, the Normal Speed accuracy figures must be doubled. Supply frequency rejection is also reduced, causing additional unquantifiable errors dependent on measurement lead layout, particularly at frequencies below 600Hz and low a.c. drive levels.

O/C and S/C Trim corrections under various conditions of interpolation, speed and level are given in the table following these Iso-Accuracy charts.

For impure components, and for measurements on the highest or lowest available ranges, the full accuracy expressions, shown below, apply. During the first hour of operation, parallel capacitance trim may drift by up to 0.05pF, series impedance by up to 0.2mΩ. Subsequent drifts, including ambient temperature change not exceeding 5°C, are included in the interpolated trim correction figures in the table (page 2-18).

If D > 0.1, multiply D accuracy by $(1 + D^2)$
High capacitance values :
D accuracy = $\pm(A + R_T \cdot \omega Cx)$

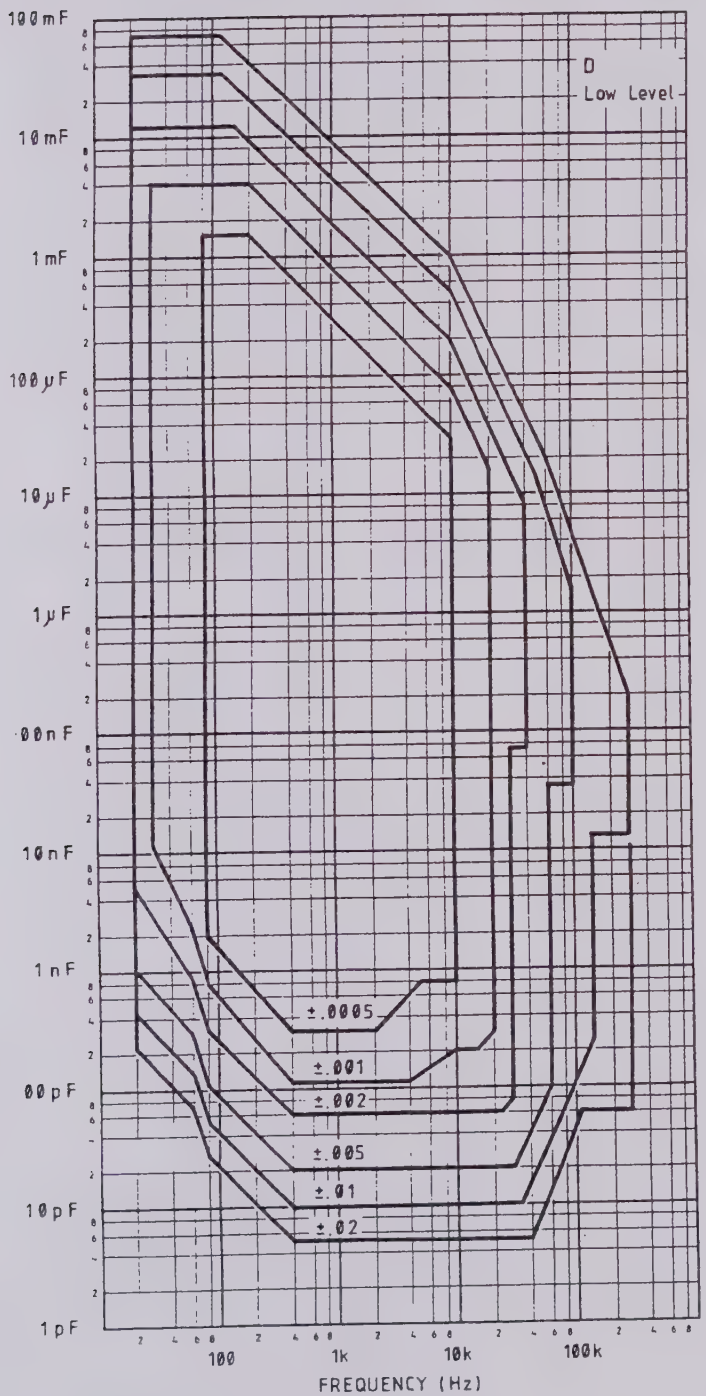
Low capacitance values :
D accuracy = $\pm (A + Y_T / \omega Cx)$

Capacitor series loss resistance (esr)
- accuracy = $\pm (A/\omega Cx)\ \Omega$
Capacitor parallel loss resistance (epr)
- accuracy = $\pm (100A.Rx/\omega Cx)\%$

where
A = Accuracy from adjacent chart
Cx = measured value of unknown component
Rx = measured value of unknown component
R_T = sum of Z_I, R_N, R_L (as appropriate, from Table - page 2-18).

Y_T = sum of Y_I, Y_N, Y_L (as appropriate, from Table - page 2-18).
ω = 2π x frequency

D Low Level Accuracy



CONDITIONS
AC Drive Level: 200mV/20mA
Slow Speed
Analyzer trimmed at measurement frequency
D ≤ 0.1
Except on highest and lowest measurement ranges, the adjacent Iso-Accuracy chart applies also as follows:
50mV - 240mV and 5mA - 24mA
Normal Speed
Interpolated trim
For Fast Speed, on all ranges, the Normal Speed accuracy figures must be doubled. Supply frequency rejection is also reduced, causing additional unquantifiable errors dependent on measurement lead layout, particularly at frequencies below 600Hz and low a.c. drive levels.

O/C and S/C Trim corrections under various conditions of interpolation, speed and level are given in the table following these Iso-Accuracy charts.

For impure components, and for measurements on the highest or lowest available ranges, the full accuracy expressions, shown below, apply. During the first hour of operation, parallel capacitance trim may drift by up to 0.05pF, series impedance by up to 0.2mΩ. Subsequent drifts, including ambient temperature change not exceeding 5°C, are included in the interpolated trim correction figures in the table (page 2-18).

If D > 0.1, multiply D accuracy by $(1 + D^2)$,
High capacitance values :
D accuracy = $\pm(A + R_T . \omega Cx)$

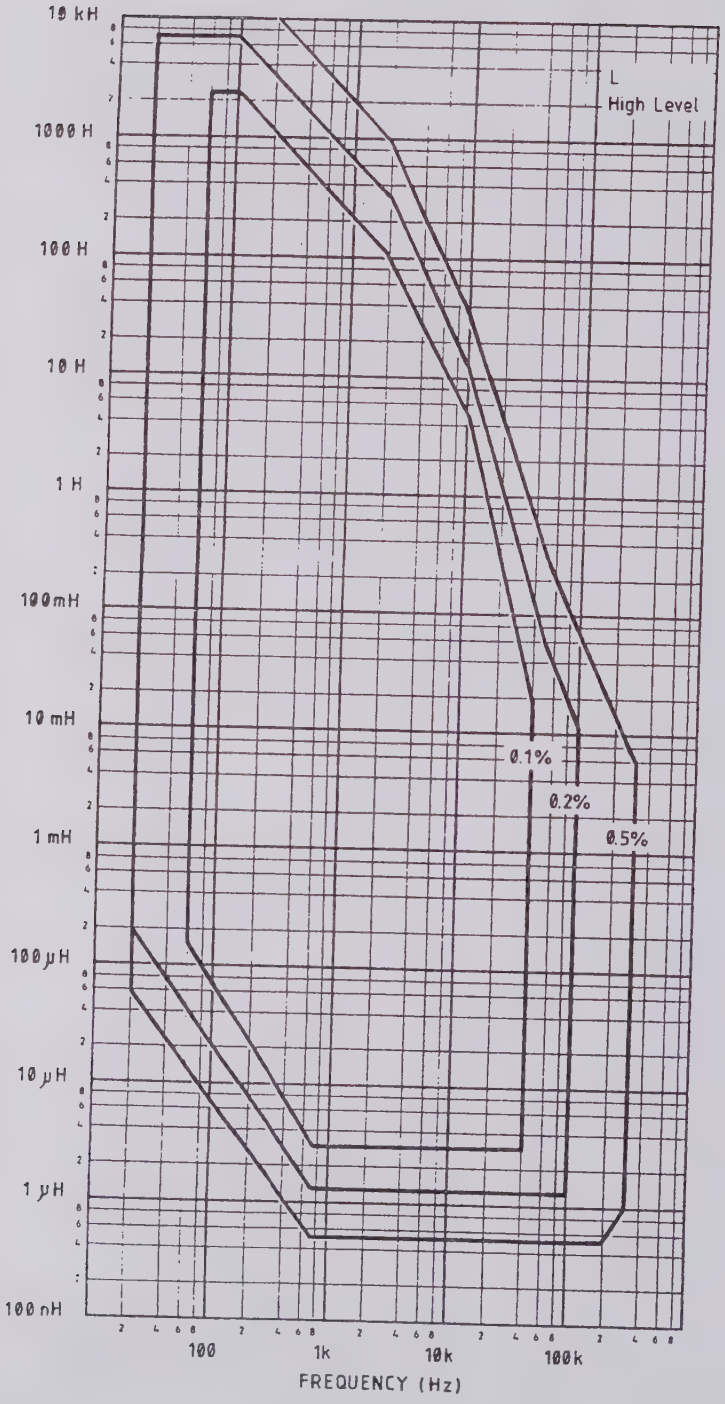
Low capacitance values :
D accuracy = $\pm (A + Y_T/\omega Cx)$

Capacitor series loss resistance (esr)
- accuracy = $\pm (A/\omega Cx)\Omega$
Capacitor parallel loss resistance (epr)
- accuracy = $\pm (100A.Rx/\omega Cx)\%$

where
A = Accuracy from adjacent chart
Cx = measured value of unknown component
Rx = measured value of unknown component
R_T = sum of Z_I, R_N, R_L (as appropriate, from Table - page 2-18).

Y_T = sum of Y_I, Y_N, Y_L (as appropriate, from Table - page 2-18).
ω = 2π x frequency

L High Level Accuracy



CONDITIONS
AC Drive Level: 1V/100mA
Slow Speed
Analyzer trimmed at measurement frequency
Q ≯ 10
Except on highest and lowest measurement ranges, the adjacent Iso-Accuracy chart applies also as follows:
250mV - 5V and 25mA - 100mA
Normal Speed
Interpolated trim
For Fast Speed, on all ranges, the Normal Speed accuracy figures must be doubled. Supply frequency rejection is also reduced, causing additonal unquantifiable errors dependent on measurement lead layout, particularly at frequencies below 600Hz and low a.c. drive levels.

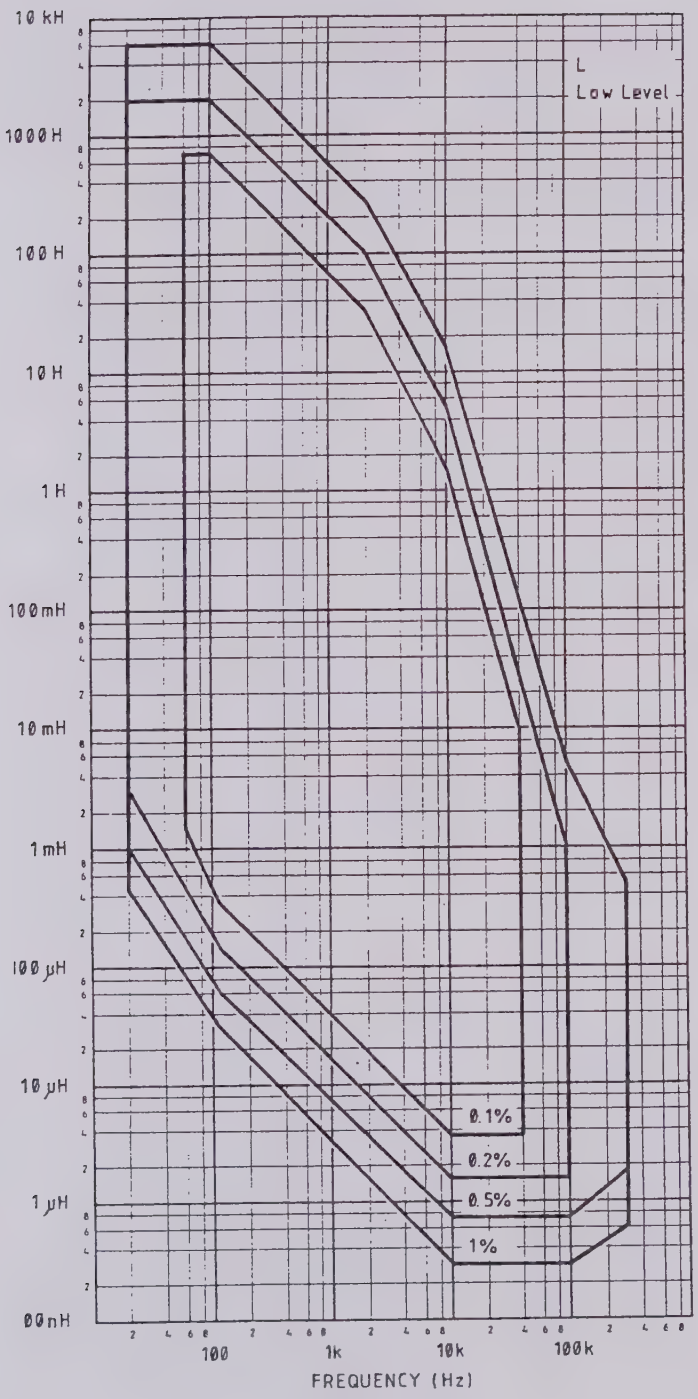
O/C and S/C Trim corrections under various conditions of interpolation, speed and level are given in the table following these Iso-Accuracy charts.

For impure components, and for measurements on the highest or lowest available ranges, the full accuracy expressions, shown below, apply. During the first hour of operation, parallel capacitance trim may drift by up to 0.05pF, series impedance by up to 0.2mΩ. Subsequent drifts, including ambient temperature change not exceeding 5°C, are included in the interpolated trim correction figures in the table (page 2-18).

If Q < 10, multiply L accuracy by (1 + 1/Q).
High L values:
Read accuracy direct from chart
Low L values:
Accuracy = $\pm (A + 100L_T / Lx)\%$

where
A = Accuracy from adjacent chart
Lx = measured value of unknown component
L_T = sum of L_I, L_N, L_L (as appropriate, from Table - page 2-18).

L Low Level Accuracy



CONDITIONS
AC Drive Level: 200mV/20mA
Slow Speed
Analyzer trimmed at measurement frequency
Q ≥ 10
Except on highest and lowest measurement ranges, the adjacent Iso-Accuracy chart applies also as follows:
50mV - 240mV and 5mA - 24mA
Normal Speed
Interpolated trim
For Fast Speed, on all ranges, the Normal Speed accuracy figures must be doubled. Supply frequency rejection is also reduced, causing additional unquantifiable errors dependent on measurement lead layout, particularly at frequencies below 600Hz and low a.c. drive levels.

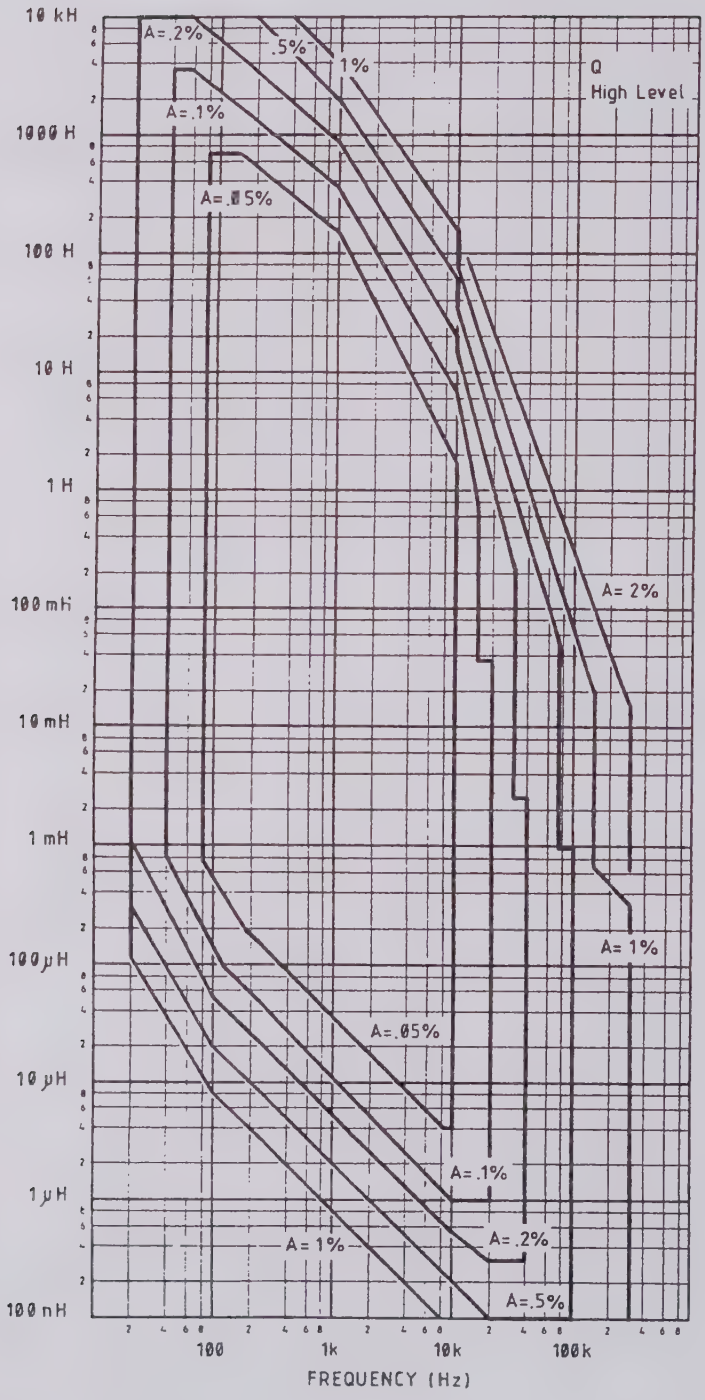
O/C and S/C Trim corrections under various conditions of interpolation, speed and level are given in the table following these Iso-Accuracy charts.

For impure components, and for measurements on the highest or lowest available ranges, the full accuracy expressions, shown below, apply. During the first hour of operation, parallel capacitance trim may drift by up to 0.05pF, series impedance by up to 0.2mΩ. Subsequent drifts, including ambient temperature change not exceeding 5°C, are included in the interpolated trim correction figures in the table (page 2-18).

If Q < 10, multiply L accuracy by $(1 + 1/Q)$.
High L values :
Read accuracy direct from chart
Low L values :
Accuracy = $\pm (A + 100L_T / Lx)\%$

where
A = Accuracy from adjacent chart
Lx = measured value of unknown component
L_T = sum of L_I, L_N, L_L (as appropriate, from Table - page 2-18).

Q High Level Accuracy



CONDITIONS
AC Drive Level: 1V/100mA
Slow Speed
Analyzer trimmed at measurement frequency
Except on highest and lowest measurement ranges, the adjacent Iso-Accuracy chart applies also as follows:
250mV - 5V and 25mA - 100mA
Normal Speed
Interpolated trim
For Fast Speed, on all ranges, the Normal Speed accuracy figures must be doubled. Supply frequency rejection is also reduced, causing additional unquantifiable errors dependent on measurement lead layout, particularly at frequencies below 600Hz and low a.c. drive levels.

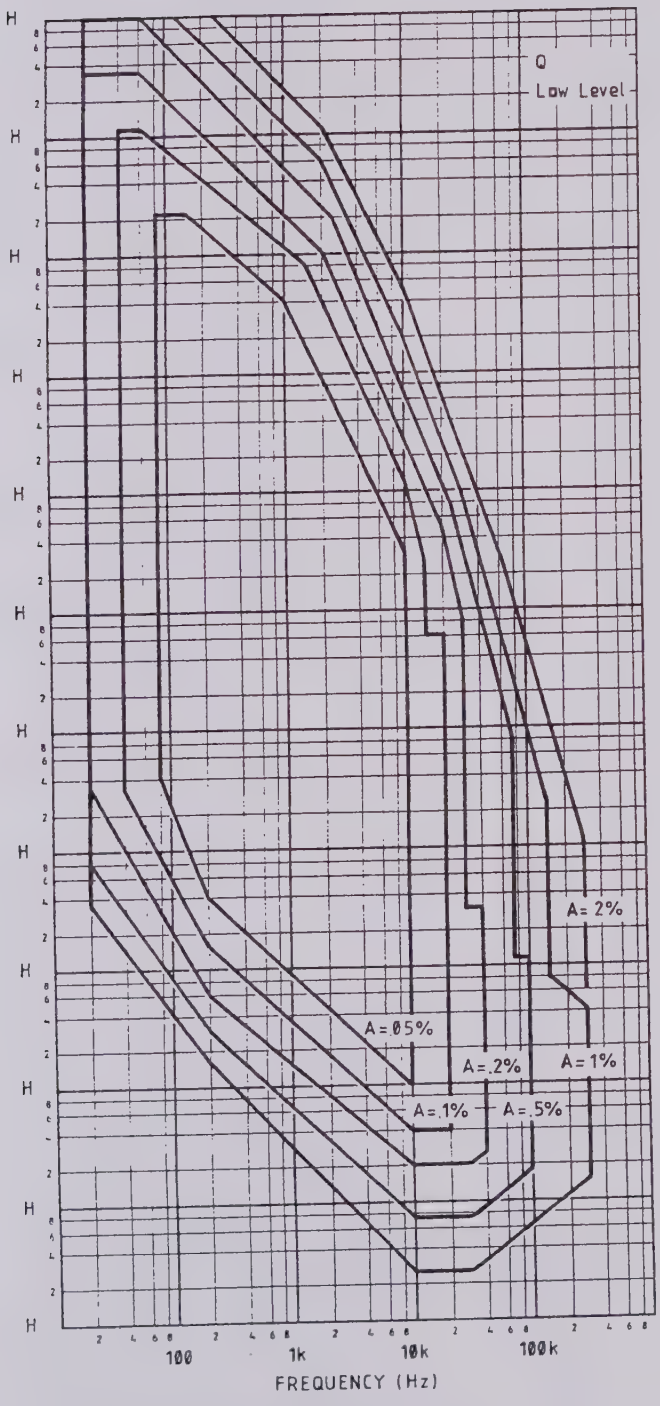
O/C and S/C Trim corrections under various conditions of interpolation, speed and level are given in the table following these Iso-Accuracy charts.

For impure components, and for measurements on the highest or lowest available ranges, the full accuracy expressions, shown below, apply. During the first hour of operation, parallel capacitance trim may drift by up to 0.05pF, series impedance by up to 0.2mΩ. Subsequent drifts, including ambient temperature change not exceeding 5°C, are included in the interpolated trim correction figures in the table (page 2-18).

For all Q values:
Q accuracy = $A(Q + 1/Q)$
High inductance values:
Read Q accuracy direct from chart
Low inductance values:
Q accuracy = $\pm(A + 100R_T/\omega Lx)(Q + 1/Q)$
Inductor series loss resistance
- accuracy = $\pm(A.\omega Lx/Rx)\%$
Inductor parallel loss resistance
- accuracy = $\pm(A.\omega LxRx)\%$
where
A = Accuracy from adjacent chart
Lx = measured value of unknown component
Rx = measured value of unknown component
R_T = sum of Z_I, R_N, R_L (as appropriate, from Table - page 2-18).

ω = 2π x frequency

Q Low Level Accuracy



CONDITIONS
AC Drive Level:200mV/20mA
Slow Speed
Analyzer trimmed at measurement frequency
Except on highest and lowest measurement ranges, the adjacent Iso-Accuracy chart applies also as follows:
50mV - 240mV and 5mA - 24mA
Normal Speed
Interpolated trim
For Fast Speed, on all ranges, the Normal Speed accuracy figures must be doubled. Supply frequency rejection is also reduced, causing additional unquantifiable errors dependent on measurement lead layout, particularly at frequencies below 600Hz and low a.c. drive levels.

O/C and S/C Trim corrections under various conditions of interpolation, speed and level are given in the table following these Iso-Accuracy charts.

For impure components, and for measurements on the highest or lowest available ranges, the full accuracy expressions, shown below, apply. During the first hour of operation, parallel capacitance trim may drift by up to 0.05pF, series impedance by up to 0.2mΩ. Subsequent drifts, including ambient temperature change not exceeding 5°C, are included in the interpolated trim correction figures in the table (page 2-18).

For all Q values:
Q accuracy = $A(Q + 1/Q)$
High inductance values:
Read Q accuracy direct from chart
Low inductance values:
Q accuracy = $\pm (A + 100R_T/\omega Lx)(Q + 1/Q)\%$
Inductor series loss resistance
- accuracy = $\pm(A.\omega Lx/Rx)\%$
Inductor parallel loss resistance
- accuracy = $\pm(A.\omega LxRx)\%$
where
A = Accuracy from adjacent chart
Lx = measured value of unknown component
Rx = measured value of unknown component
R_T = sum of Z_I, R_N, R_L (as appropriate, from Table - page 2-18).

$\omega = 2\pi \times$ frequency

O/C TRIM CORRECTIONS f = frequency in kHz

	INTERPOLATION		NORMAL SPEED		LEVEL .5 - 5V		LEVEL .25V		LEVEL .1V		
FREQUENCY RANGE (Hz)	Y_I (nS)	C_I (pF)	Y_N (nS)	C_N (pF)	Y_L (nS)	C_L (pF)	Y_L (nS)	C_L (pF)	Y_L (nS)	C_L (pF)	
20-60	.13	.02/f	.04	.007/f	.2	.032/f	.2	.032/f	.5	.08/f	For drive levels below .1V multiply level corrections by .1V/level.
80-1k	.13	.02/f	.03	.005/f	.1	.016/f	.2	.032/f	.5	.08/f	
1k2-10k	.13xf	.02	.02	.003/f	.1xf	.016	.2xf	.032	.5xf	.08	
12k-60k	.2xf	.032	.01xf	.002	.16xf	.025	.32xf	.05	1.3xf	.2	
75k-300k	1.6xf	.25	.03xf	.005	.32xf	.05	.64xf	.1	4xf	.6	

S/C TRIM CORRECTIONS f = frequency in kHz

	INTERPOLATION		NORMAL SPEED			LEVEL = 50mA			
FREQUENCY RANGE (Hz)	Z_I (μΩ)	L_I (nH)	R_N (μΩ)	X_N (μΩ)	L_N (nH)	R_L (μΩ)	X_L (μΩ)	L_L (nH)	
20 - 60	300	50/f	50	25	4/f	125	125	20/f	For drive levels below 50mA multiply level corrections by 50mA/level.
80 - 250	120	20/f	25	25	4/f	125	125	20/f	
300 - 10k	50	8/f	25	25	4/f	40	20	3.2/f	
12k - 30k	4xf	1.0	25	25	4/f	4xf	2xf	.4	
40k - 100k	30xf	5	.5xf	0	0	$.13xf^2$	$.065xf^2$	.01xf	
120k- 300k	30xf	5	.5xf	0	0	13xf	6.5xf	1.0	

3 INSTALLATION

3.1 POWER CONNECTION

Check that the instrument is correct for the supply frequency (50 or 60Hz) and for the supply voltage (230V or 115V). The voltage setting is shown on a reversible plate on the rear of the instrument. To obtain the alternative setting, disconnect the instrument from the ac supply, remove the plate, re-set the switch and replace the plate with the new setting showing. Ensure that the fuse rating is correct:

230V instruments	1A-T
115V instruments	2A-T

The frequency (50 or 60Hz) for which the instrument was factory-set is marked on the rear panel. Operation from supplies of the wrong frequency will not cause damage, but noise levels may be higher on some readings. To reset instruments for the alternative frequency, contact your supplier.

Wire the free end of the power lead as follows:

Yellow/Green	to	Earth (Ground)
Brown	to	Live
Blue	to	Neutral

If the plug is fused, a 3-amp fuse should be fitted.

The instrument is not suitable for battery operation.

Allow up to 10 seconds for the crt display to warm up.

A rear panel control adjusts the display brightness to suit local ambient lighting levels.

3.2 SAFETY

An adequate ground connection is essential to ensure operator safety. Very high voltages are present in the Analyzer : case panels should not be removed except by qualified personnel and then only when the instrument has been completely disconnected from the ac supply for several minutes.

3.3 RACK MOUNTING

A rack mounting kit (part number 25539) consisting of brackets (ears) and screws is available from your supplier, but runners must also be used to support the weight of the instrument. Top and bottom covers must remain in position, when the Analyzer is rack-mounted, but free ventilation must be allowed to the slots in the covers and to the heat sink at the rear of the instrument.

3.4 MEASUREMENT CONNECTIONS

Accessory type 1605, four-terminal leads terminated with Kelvin clips, is supplied as standard equipment with the instrument. Ensure that the colour-coded plugs are mated correctly with the corresponding panel sockets.

Accessory type 1505, four-terminal leads terminated with crocodile clips, (see Fig. 3.1) is available to order.

Component fixture type 1005, (Fig. 3.2), also available to order, provides four-terminal connections to components with either radial or axial leads. A cable is provided to link the fixture to the trigger socket on the Analyzer. Manual triggering (see Single/Rep modes, section 5.16) can then be obtained using the key on the Analyzer or the one provided on the fixture.

Further information on 2, 3 and 4-terminal connections is given in section 5.21.

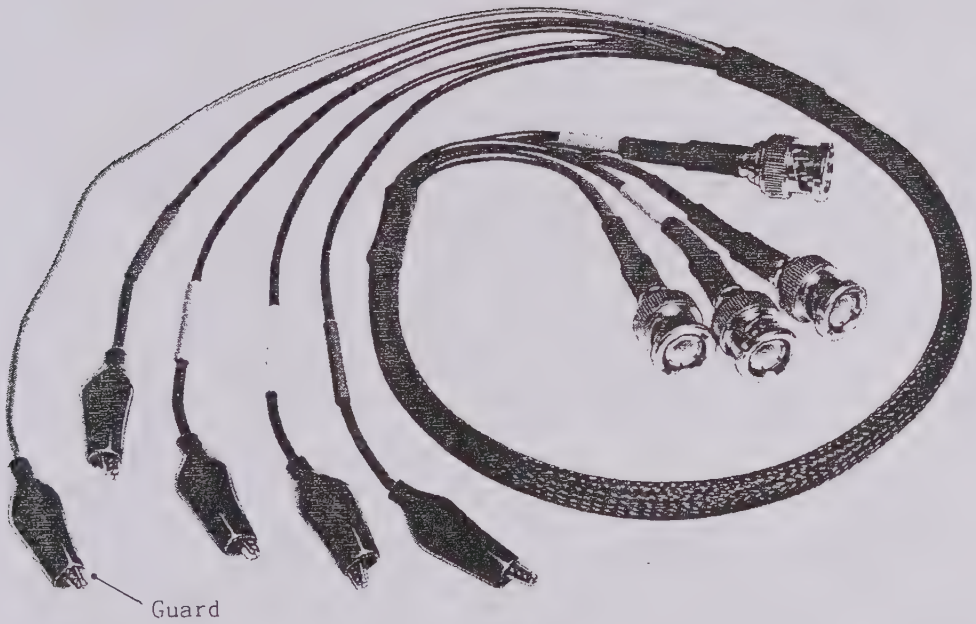


Fig. 3.1 Crocodile clip leads type 1505

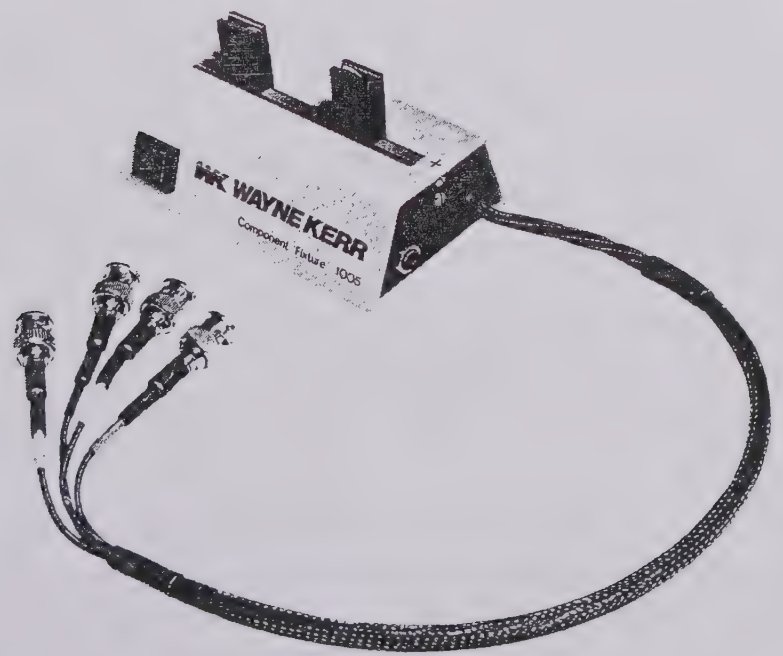


Fig. 3.2 Component Fixture type 1005

4 BASIC INFORMATION

4.1 PANEL ARRANGEMENT

An introduction to the Analyzer operation falls into the same three parts as the instrument front panel, that is : Display, Master Controls and Keypad (see Fig. 4.1).

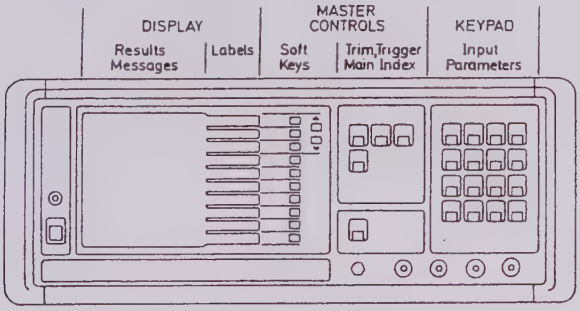


Fig. 4.1 Panel Controls

The Display is a cathode-ray tube, the main area showing results in numeric and graphic form, together with instructions, warnings, messages, and information on parameters selected or needed. The right-hand side of the crt display labels the row of ten 'soft' keys whose functions depend on the type of operation in progress.

The Master Controls consist of the ten 'soft' keys and five with dedicated functions. Two select either Trim O/C or Trim S/C. The Trigger key initiates the selected Trim operation, or a measurement in the 'single shot' mode. Pressing 'Local' restores control to the front panel when the (optional) GPIB mode is in use. The fifth key in this group is Main Index, which calls up a list of the various operating modes available. A summary of these modes is given in the next few pages, in the sequence they appear as labels for the soft keys (when Main Index has been selected). The required mode is obtained by pressing the appropriate soft key. Detailed information appears later in the Manual.

The Keypad provides the means for input of numerical values, multiples and units, or % figures for establishing and/or updating limits for sorting and pass/fail operations. Full details of its use appear in various later sections of this Manual.

4.2 MODE SUMMARIES

Normal is the usual operating mode for obtaining measurements of component values in absolute terms, together with such secondary characteristics as Q, D and loss resistance. A typical display in the Normal mode is shown in Fig. 4.2.

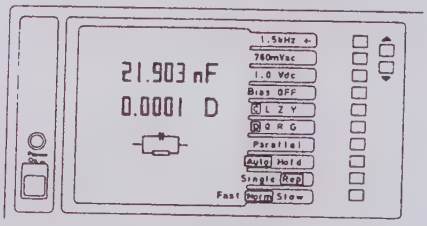


Fig. 4.2 A typical Normal mode display

From the illustration, it can be seen that - in this mode - the functions of the ten soft keys fall logically into three groups:

1 The top four establish the conditions of measurement: test frequency (see 5.2), test voltage (or current) (5.3), bias level and bias on/off (5.4).

2 The next three keys select the type of readout wanted for display: major term, minor term and alternatives of values for equivalent series or parallel circuits. The major* term can be capacitance, inductance, impedance or admittance.
The choice available for minor* term depends on the major term selected. With C or L selected, the choice is D, Q, R (series or parallel) or G (parallel only). With Z or Y selected, the choice is phase angle or ac current (on ranges giving ac voltage drive). For impedance below 10 ohms, where constant current drive is provided, the choice becomes phase angle or ac voltage.

3 The lowest three keys determine the operating mode: Automatic range selection or Hold (section 5.15), single-shot or repetitive measurements (5.16), and the rate required for repetitive measurements (5.17).

To the right of the uppermost keys are two keys for increasing or decreasing the selected parameter (indicated by an arrow).

* For simplicity of reference, "major" and "minor" are used for the terms as listed above. Strictly speaking, of course, R and G can be major terms when measuring a resistive Unknown.

Deviation mode is used for logging changes with time, temperature, frequency, level or dc bias, or for comparing components in a batch against a known good reference. It provides direct readout in % of the change in a major term from a previously measured (non-volatile) reference value. Further information on Deviation is in section 5.18.

Limits mode, intended for Goods Inwards checking, is similar to Deviation but the Nominal value, and/or upper and lower pass limits - all held in non-volatile memory - are keyed in by the operator. Checks can be made in % or absolute terms, on major or minor terms. The Limits mode also incorporates an Analog Bar display, useful for rapid adjustment of preset components. Further information on Limits is in section 5.19.

Bin Set/Bin Sort/Bin Count. These modes cater for the binning operation, which classifies components into Bin 0 to 8, according to their measured value and/or minor term, with Bin 9 provided for rejects. The Bin Set mode is used to select % or Abs and the appropriate non-volatile limits for each bin. Pressing the Bin Sort key initiates the binning operation. Bin Count is a non-volatile data logging mode which stores the total number of measurements falling into each bin, together with the batch total. Further information on binning is in section 5.20.

Connections mode provides a display of 2, 3 and 4-terminal connections, together with explanatory comments, as shown in Fig. 4.3. It is provided for reference only and is not an operating mode. Information on connections was summarized in section 3.4. For further details see sections 5.1 and 5.21.

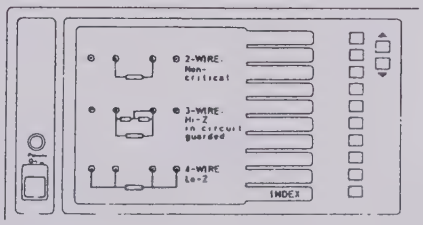


Fig. 4.3 Connections display

5 OPERATION

5.1 TRIMMING

When the Analyzer is trimmed, the values to compensate for stray capacitance and series impedance of the test leads/fixtures are held in non-volatile stores. They are applied automatically at all frequencies, levels and ranges. Thus, for the majority of measurements, no re-trimming is necessary. The exceptions are when the test connections are changed, and when the highest possible accuracy is required for measurements of very high or very low impedances. (See the sections on measuring small-value capacitors, 5.5, and measuring small-value inductors, 5.6).

During trimming, the Analyzer makes measurements at a number of frequencies, storing the complex admittance or impedance values for each. These measurements are made at a level of 1V on Trim O/C or 100mA on Trim S/C, and the frequencies used include 100Hz*, 1kHz, 10kHz, 100kHz together with the measurement frequency in use when trimming was initiated. If the measurement frequency is subsequently altered, the Analyzer automatically applies a new correction value derived from the stored values by interpolation.

* 120Hz when operating from 60Hz supplies.

continued .....

Trim O/C

1 Press Trim O/C and open circuit the test leads (see Fig. 5.1). Clips should be at least 5cm apart.

2 Press Trigger. The series of operations can take several seconds. When trimming is complete, the Analyzer reverts to its previous settings.

Trim S/C

1 Press Trim S/C. Clip the leads to a piece of wire or a component lead, as close together as possible (as in Fig. 5.1). Do not connect the clips directly to each other (this cannot provide the necessary 4-terminal short circuit). With component fixture type 1005, connect heavy gauge tinned copper wire between the measurement jaws.

2 Press Trigger. After several seconds, the Analyzer will revert to its previous settings.

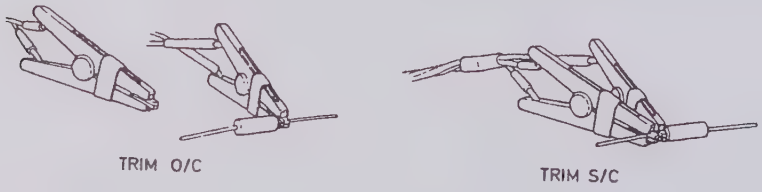


Fig. 5.1 Trim connections

5.2 FREQUENCY SELECTION

Pressing the NORMAL key (the uppermost one when Main Index is displayed) will produce a display similar to that shown in Fig. 4.2. The actual frequency shown will be the last value selected, held in a non-volatile store. The frequencies available (in Hz) are : 20, 25, 30, 40, 50, 60, 80, 100, 120, 150, 200, etc, repeating each decade up to 60k, then 75k, 100k, 120k, 150k, 200k, 300k. Two methods are available for changing the frequency. For either method, the set-up arrow should be pointing to the frequency. If necessary, press the topmost soft key to bring the arrow to this position.

The first method is to use the two keys (▲ and ▼, respectively) to increase or decrease the frequency to any of the discrete values listed above. Holding down either of these keys will produce a continuous increase (or decrease) which, after a short while, becomes faster. The change ceases when the upper (or lower) limit is reached.

The second method is to select the required frequency directly by the keyboard. As the value is keyed, the figures are shown at the bottom of the main display. If the frequency is in kilohertz, follow the number(s) by pressing Units and k. Check the display and press Enter to select the keyed value, or Clear to correct keying errors. If the frequency keyed in is not one of the discrete values listed above, the Analyzer will select the nearest frequency available.

Note: The measurement process is interrupted while keying-in data, and recommences when either Enter or Clear is pressed.

5.3 TEST SIGNAL DRIVE LEVEL

As shown in Fig. 4.2, the second from top soft key, in the NORMAL mode, shows the drive level of the ac test signal. There are 8 measurement ranges and the maximum drive level available depends on the range in use (whether selected in the Auto mode or one chosen by the operator in the Hold mode). These levels are as follows:

Range	Impedance range	Max.drive level (rms)
1	<1.25Ω	100mA
2	<10Ω	100mA
3	>10Ω	1V
4	>80Ω	5V
5	>640Ω	5V
6	>5.12kΩ	5V
7	>41kΩ	5V
8	>328kΩ	5V

Above 10kHz, highest range: 7
" 60kHz, " " : 6
Drive levels below 25mA, lowest range: 2
" " " 25mV, highest " : 7 (to 10kHz)
" " " " , " " : 6 (above 10kHz)
" " " " , " " : 5 (above 60kHz)
At 300kHz, the maximum drive available is 3V.

The range number can be displayed or extinguished (top left) by keying 'Code 9,Enter' (the selection is volatile).

The procedure for changing the drive level is similar to that for frequency selection (section 5.2). With the set-up arrow against the drive level, the value can be re-set using the up/down arrow keys or the numeric keypad.

If a drive level exceeding 1V has been selected, and the Analyzer is subsequently switched to Range 3, (whether selected manually, or automatically as a result of a change in frequency or in the Unknown itself), the level will automatically be reduced to 1V. When the Analyzer changes from voltage drive to current drive, or vice versa, the new level is the equivalent value with a 10-ohm Unknown (e.g. 1 volt becomes 100mA; 20mA would become 200mV). In all these situations, a warning message always appears.

5.4 DC VOLTAGE BIAS

A programmable internal supply can provide up to 20V dc bias across the test component during ac measurements. In the NORMAL mode, the fourth from top soft key operates as a toggle for Bias ON/OFF*. The third from top soft key is used to place the set-up arrow prior to use of the up/down arrow keys or the numeric keypad to select the required bias level. The procedure is similar to that for frequency selection (section 5.2).

WARNING

> Never connect solid tantalum capacitors while Bias is ON. The surge current could damage the capacitor.

A safety link on the rear panel must be fitted before the bias function is available. Connect the unknown component (+ve to the Kelvin clip with red sleeves on its handles) before selecting Bias ON. Up to 1A current is available for rapid charging of large-value electrolytic capacitors, although the rate of charge is limited to below 0.5V/ms to avoid damage to solid tantalum capacitors and other sensitive components. Measurement will not commence until the required dc voltage is established. Select Bias OFF and allow the capacitor to discharge before disconnection.

The voltage range can be extended to a total of 50V maximum by connecting an external ground-free power supply between the bias link terminals. Because the Analyzer protection is limited in this mode, it is essential to observe the correct polarity and to keep the voltage to a maximum of 30V when the internal supply is at 20V. Bias at the measurement terminals is the sum of the internal and external voltages. With an external supply fitted, always select Bias OFF before reducing the internal voltage setting.

IMPORTANT

Remove the safety link on the rear panel as soon as use of the bias supply is no longer required. This will prevent a dc voltage being applied to resistors or inductors if Bias ON is inadvertently selected during measurements other than capacitance.

* At power-up, the condition is always Bias OFF and a message to this effect is displayed until keying operations commence.

5.5 CAPACITANCE MEASUREMENT (refer to Fig. 4.2, page 4-2)

If bias will be required, check that the rear-panel safety link is fitted.

1 In the NORMAL mode, use the C/L/Z/Y key to select C.

2 Connect the capacitor.

3 Set up the required frequency (see section 5.2) and (if applicable) bias voltage (see 5.4).

4 Select D, Parallel, Auto, Rep and Norm (the alternatives to these are described later).

5 When the Analyzer has Auto-ranged (or when Range has been selected manually, see Auto/Hold modes, section 5.15), set up the required drive level (see section 5.3) and (if required) select Bias ON.

6 The display will show the numerical value and units (in Fig. 4.2, 21.903nF),the dissipation factor (0.0001D) and a diagram of C and R in parallel.

7 Select Bias OFF (if applicable) and disconnect the capacitor.

Loss Resistance. As an alternative to D, R can be selected to produce a readout of the loss resistance of the capacitor.

For electrolytics and other decoupling capacitors, the preferred readout is usually ESR (equivalent series resistance).

For other classes of capacitor, EPR (equivalent parallel resistance) is more commonly used.

Formulae relating series/parallel loss resistance with C and D are given in section 7.

Effect of series inductance. Series inductance will resonate with capacitance at a frequency f_o. At frequencies below resonance, the apparent capacitance will increase. Above resonance, the impedance becomes inductive, giving a negative capacitance reading.

To establish the value of the series inductance, L_o, measurements must be made at two frequencies, f_1 and f_2. If C_1 and C_2 are the two corresponding capacitance readings obtained, the series inductance is given by:

$$L_o = \frac{C_1 - C_2}{C_2 C_1 (\omega_2^2 - \omega_1^2)}$$

where ω = 2π x frequency.

The resonance frequency is given by:

$$f_o = \sqrt{[(f_1^2 C_1 - f_2^2 C_2)/(C_1 - C_2)]}$$

C_1 and C_2 may be +ve or -ve : the sign must be included with the value in the above expressions.

Measuring small-value capacitors. For the best accuracy when measuring small-value capacitors it is necessary to trim the bridge (O/C) at the frequency to be used for the measurement, and to ensure that the leads are not moved between the trimming and the measurement. A level of 1V is an optimum value for minimizing lead errors, as this is the level used during the trimming operation.

Measuring electrolytic capacitors. The procedure for applying bias to capacitors during measurement is described in section 5.4. The polarity is marked on one of the front-panel lead connectors. The corresponding positive Kelvin clip is identified by red sleeves on the handles. Electrolytic capacitors are normally measured at 100 or 120Hz, in series configuration.

Charged capacitor protection. The Analyzer has internal protection against the accidental connection of charged capacitors (either polarity) to the measurement leads. Assuming that no dc bias is in use, the protection is:

500V up to 2μF
150V up to 100μF
100V up to 1000μF
50V up to 100mF

These figures apply to capacitors connected between inners of the 'orange' and 'red' leads, or between 'orange' and Ground (where the colours are those of the associated panel connectors). If bias is in use, the extent of the protection may be reduced.

WARNING

Connection of a charged capacitor between 'red' and Ground may blow an internal 1.6-amp fuse.

5.6 INDUCTANCE MEASUREMENT

To avoid accidental application of bias, ensure that the rear-panel safety link is not fitted.

1 In the NORMAL mode, use the C/L/Z/Y key to select L.

2 Connect the inductor.

3 Set up the required frequency (see section 5.2).

4 Select Q, Series, Auto, Rep and Norm (the alternatives to these are described later).

5 When the Analyzer has Auto-ranged (or when Range has been selected manually), set up the required drive level (see section 5.3).

6 The display will show the numerical value and units (for example 7.24mH), the quality factor of the inductor (e.g. 2.9Q) and a diagram of L and R in series.

Loss Resistance. As an alternative to Q, R can be selected to produce readout of the loss resistance of the inductor. Also, values for the equivalent parallel circuit can be selected instead of the more usual series configuration.

Formulae relating series/parallel loss resistance with L and Q are given in section 7.

Effect of self-capacitance. Self-capacitance will resonate with inductance at a frequency f_0. At frequencies below resonance, the apparent inductance will increase. Above resonance, the impedance becomes capacitive, giving a negative inductance reading.

To establish the value of the self-capacitance, C_0, measurements must be made at two frequencies, f_1 and f_2. If L_1 and L_2 are the two corresponding inductance readings obtained (in parallel representation), the self-capacitance is given by:

$$C_o = \frac{L_2 - L_1}{L_2 L_1 (\omega_2^2 - \omega_1^2)}$$

where ω = 2π x frequency.

The resonance frequency is given by:

$$f_o = \sqrt{[(f_2^2 L_2 - f_1^2 L_1) / (L_2 - L_1)]}$$

L_1 and L_2 may be +ve or -ve: the sign must be included with the value in the above expressions.

Measuring small-value inductors. The Analyzer measures the difference between the inductance of S/C trimming and the test item fitted into the same location. Therefore, stable lead arrangements are essential for low inductance measurements; use of the component fixture, accessory 1005, is recommended. When using the fixture, S/C trim is achieved by placing a wire across the jaws.

A 5cm length of 1mm wire has an inductance of 0.05μH.
A 5cm length of 2mm wire has an inductance of 0.04μH.

The Q is always low, but self-capacitance is not a problem at the 6425 measurement frequencies. For best inductance measurement results, work at 10kHz in series configuration. Where possible, measure at 100mA as this is the signal level used during trimming.

It must be appreciated that when an inductor is measured at a frequency much lower than that for which it is designed (e.g. an h.f. choke tested at a.f.) it will tend to behave as an inductive resistor. In these circumstances, the inductance measurement accuracy is widened by the factor (1 + 1/Q). The value of this factor can be determined by using the Q feature.

Air-cored coils are particularly susceptible to hum pick-up. For this reason, keep them well clear of power transformers, away from the scan coils of the Analyzer and, whenever possible, measure at 10kHz. If low-frequency measurements are required, and trouble persists, use Slow setting.

Measuring iron-cored inductors. The effective value of all iron-cored inductors can vary widely with the magnetization and, therefore, with the level of the test signal. Ideally, they should be measured at the frequency of use, with the same ac and dc levels as apply in use. When core materials can be damaged by excessive magnetization (for example, some tape heads and microphone transformers), check before connection that the test signal level is acceptable. If the ac test signal does not generate sufficient core flux, arrangements should be made for the inductor to pass dc during measurement. The essential requirements are to prevent this current entering the instrument measurement circuits, and to minimize the effect of the dc supply components on the measured value. Wayne Kerr Precision Inductance Analyzer, model 3245, is designed specifically for such measurements and, with one or more model 3220 Bias Units, up to 100 amps DC can be passed. However, the 6425 can perform very valuable measurements with DC passing, as described in the next section.

Inductors passing DC. The arrangement is a special case of the Analyzer's ability to measure a component in the presence of shunt elements (details are in 5.21: In-circuit measurements).

AC measurements can be performed on inductors or other components passing direct current by using the circuit arrangement shown in Fig. 5.2. The DC passes through Zs, Zd and Lu in series, and is prevented from entering the Analyzer current detector by the blocking capacitors as shown in the figure.

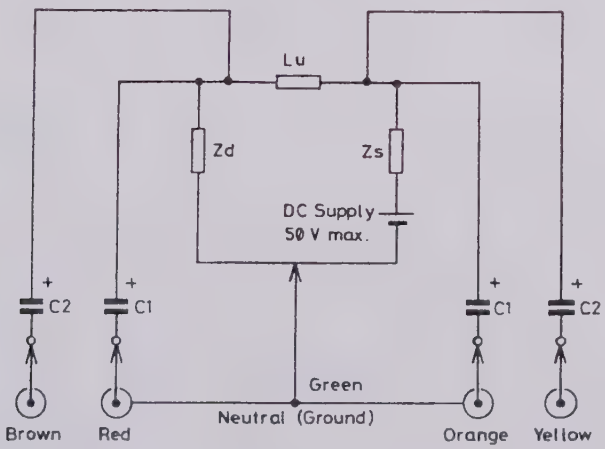


Fig. 5.2 Inductors passing DC

The components Zs and Zd may be resistors, although the use of chokes will reduce power dissipation and supply voltage, particularly at higher currents. The required ac impedance varies with measurement range and frequency and may be found by reference to section 5.21. If chokes are used they should be adequately gapped to prevent the core becoming saturated by the direct current. For operation at a single frequency, the impedance of each choke can be raised by connecting a parallel resonating capacitor. The value of this is given by $\frac{1}{(2\pi f)^2 L}$, from which should be subtracted the self-capacitance of the choke.

The value of C1 in Fig. 5.2 should be 100μF for frequencies of 10kHz or above, rising to 1mF at 1kHz and 10mF at 100Hz. Note that the charging current of this capacitor flows directly into the current sense terminal of the Analyzer, which is internally fused at 1.6A. If the dc bias is to exceed 1A, take care to increase the supply gradually from zero to avoid blowing this fuse, and similarly to decrease it gradually to zero before removing the inductor under test. C2 may be of lower value, perhaps 10% of C1.

WARNING

To avoid the danger of electric shock, always set the direct current to zero before disconnecting the inductor under test. Back-emf voltages can be dangerous even at bias currents below 100mA.

5.7 IMPEDANCE MEASUREMENT (see also section 5.14)

If the component could be damaged by dc bias, ensure that the rear-panel safety link is not fitted.

1 In the NORMAL mode, use the C/L/Z/Y key to select Z.

2 Connect the component(s) or network.

3 Set up the required frequency (see section 5.2).

4 Select Angle, Auto, Rep and Norm (the alternatives to these are described later).

5 When the Analyzer has Auto-ranged (or when Range has been selected manually), set up the required drive level (see section 5.3).

6 The display will show the value of the impedance in Ohms and the angle (in degrees) between the voltage and current. By convention, a positive phase angle implies an inductive impedance.

5.8 ADMITTANCE MEASUREMENT (see also section 5.14)

If the component could be damaged by dc bias, ensure that the rear-panel safety link is not fitted.

1 In the NORMAL mode, use the C/L/Z/Y key to select Y.

2 Connect the component(s), network or conductivity cell.

3 Set up the required frequency (see section 5.2).

4 Select Angle, Auto, Rep and Norm (the alternatives to these are described later).

5 When the Analyzer has Auto-ranged (or when Range has been selected manually), set up the required drive level (see section 5.3).

6 The display will show the value of the admittance in Siemens (S) and the angle (in degrees) between the voltage and current. By convention, a positive phase angle implies capacitive admittance.

5.9 RESISTANCE MEASUREMENT

If the component could be damaged by dc bias, ensure that the rear-panel safety link is not fitted.

1 In the NORMAL mode, set up the required frequency (see section 5.2).

2 Connect the resistor.

3 Selection of the 'major' term must be C or L for R to become available at the 'minor' term key. The choice depends on the resistance value, which also determines the preferred selection of Parallel or Series.

For resistors above 1000 ohms, select C, R and Parallel
" " below " " " L, R " Series

4 Select Auto, Rep and Norm (the alternatives are described later).

5 When the Analyzer has Auto-ranged (or when Range has been selected manually), set up the required drive level (see section 5.3).

6 Beneath the small C or L value, the display will show the resistance value in Ohms and a diagram of parallel C/R or series L-R.

Note: It is not unusual for small changes to occur in the measured value of a resistor when the test frequency is changed. The effect can be caused by small reactive terms (which are present with all resistors) or by skin effect. Their effect is minimal when tests are made at 100/120Hz. The high resolution of the instrument may also show up variations in resistance due to temperature changes.

5.10 CONDUCTANCE MEASUREMENT

If the component could be damaged by dc bias, ensure the the rear-panel safety link is not fitted.

1 In the NORMAL mode, set up the required frequency (see section 5.2).

2 Connect the component or conductivity cell.

3 Selection of the 'major' term must be C or L for G to become available at the 'minor' term key. It is normal to select C.

4 Select Parallel, Auto, Rep and Norm (the alternatives to these are described later: Series is not available with G).

5 When the Analyzer has Auto-ranged (or when Range has been selected manually), set up the required drive level (see section 5.3).

6 Beneath the L or C value, the display will show the conductance in Siemens (S) and a diagram of parallel L/G or C/G.

5.11 D & Q MEASUREMENTS

Normally, D will be selected when making capacitance measurements (section 5.5) and Q with inductance (5.6). However, the Analyzer can equally well be set to read D with L, or Q with C. The expressions for D and Q, for series and parallel capacitive or inductive circuits, are in the Theory Reference section (7).

Note. Q is computed by the Analyzer from 1/D. Therefore, with low-loss coils, as D becomes very small, the high Q reading is likely to fluctuate. It follows that in these circumstances the accuracy and resolution are limited (see Specification).

5.12 UNKNOWN CURRENT/VOLTAGE

As described in section 5.3, the test signal level is a function of the range in use, and is a current drive for impedances below 10 ohms and a voltage drive on all other ranges. When the major term selection is Z or Y, the 'minor term' key offers either Vac or Iac as an alternative to Angle (described in section 5.14). On ranges 1 and 2 (current drive), the 'minor term' key makes Vac available - a measure of the voltage developed across the unknown (see Fig. 5.3). Above 10 ohms, the alternative to Angle is Iac - a measure of the current passed by the test component. This feature is invaluable when examining the properties of non-linear devices, and for checking that signal levels are within permitted limits for sensitive devices.

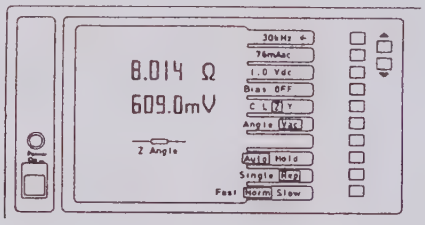


Fig. 5.3 Unknown Current/Voltage display

5.13 SERIES/PARALLEL EQUIVALENTS

At a given frequency, a two-terminal R,C,L network can be represented in polar form (sections 5.7, 5.8 and 5.14) or in fully equivalent series or parallel circuits. The Analyzer can be set to display values in series or parallel format (not series for G) although, as a general guide, parallel will be preferred for components whose impedance exceeds 1000 ohms, and series for components below this value.

It is worth noting that, for a relatively pure component, the major term will remain substantially the same in series or parallel representation. A small L, C or R term in a series circuit is equivalent to a large term in the parallel equivalent, and vice versa. D and Q values are independent of series/parallel selection.

It must be remembered that series/parallel equivalents obtained at one frequency are NOT applicable at any other frequency. No computations have to be made by the operator but, for reference, the appropriate formulae are given in the Theory Reference section (7).

5.14 POLAR MEASUREMENTS (Z/Angle & Y/Angle)

Sections 5.7 (Impedance measurement) and 5.8 (Admittance measurement) describe the procedure for obtaining measurements in polar form :

$$|Z| \quad \angle\theta$$

or

$$|Y| \quad \angle\theta$$

where $|Z|$ is the modulus of the impedance

$|Y|$ " " " " " admittance

and $\angle\theta$ is the phase angle, assumed
positive for inductive impedance
negative for capacitive impedance
positive for capacitive admittance
negative for inductive admittance

Note that δ (used in the expression $D = \tan \delta$) is $(90 - \theta)°$.

Formulae relating resistive and reactive terms to Polar measurements are given in the Theory Reference section (7).

5.15 AUTO/HOLD MODES

The Analyzer has eight measurement ranges, listed in section 5.3. For most measurements, it is convenient to use the Auto mode and leave the Analyzer to select that range giving the best accuracy. In some situations, however, users will prefer to pre-select a particular range, or to hold the instrument on the range it has selected in the Auto mode. The latter can be used to speed measurements on a batch of similar components. In this condition (unless single-shot mode is used) the display will show Range Error while no component is fitted.

To display (or extinguish) the range number in use, key in 'Code 9, Enter'*. In the Hold mode, the range can be changed manually by keying Codes 1 to 8. For example, to select range 4, key in 'Code 4, Enter'. In the Hold mode, Range Error will be indicated when a change of range would give better measurement accuracy. If the value is completely beyond the capability of the range selected, the display is blanked.

* At power-up, the range will be the one last selected, but the number will not be displayed until 'Code 9, Enter' is keyed.

5.16 SINGLE/REP MODES

With Single selected, the readout of the last measurement remains displayed until Trigger is pressed. Remote tiggering is possible by connecting a single-pole switch (push-button or footswitch) across the 3.5mm jack below the Trigger key. (Note that there is a small voltage present on both contacts of the jack, therefore neither side must be Grounded). Component fixture type 1005 has a trigger push-button. At each triggering, the instrument makes a new measurement.

In the repetitive mode, the Analyzer automatically performs a continuous series of measurements, updating the display as each one is completed. The rate of this repetition is detailed in the next section.

5.17 FAST/NORM/SLOW MODES

The Normal rate for repetitive measurements is approximately 2.5 measurements per second, for test frequencies of 300Hz or higher. Below 300Hz the measurement period increases progressively to about 600ms per measurement at 20Hz. Full specified accuracy is obtained in the Normal mode, except when measuring very low or very high impedances. See Specification (section 2).

The Slow rate is approximately 1.3s per measurement, becoming 750ms per measurement at 100kHz and above. The Slow setting improves the display resolution by 2:1 with a corresponding improvement in signal/noise. Rejection of supply frequency pick-up improves in this mode, particularly when the test frequency is not a multiple of the supply frequency.

The Fast setting increases the measurement rate to about 8 per second, and is useful when setting adjustable components or for speeding operation under remote control. Basic accuracy on Fast is 0.1% but rejection of supply frequency pick-up is poor. Measurement noise is minimized by screening (connect braid to Ground or green measurement lead). Below 300Hz, the measurement period increases progressively to about 600ms at 20Hz.

On the Fast setting, speed is affected by internal computations. For the fastest results, avoid the polar format, use Series for ranges 1 - 4, and Parallel for ranges 5-8. Also, use range Hold (see 5.15).

5.18 DEVIATION

As stated in 4.2, this mode provides direct readout in % of changes to C, L, Z or Y from a previously measured reference value. (For resistance, Z is used, and for conductance, Y). A typical Deviation display is shown in Fig. 5.4.

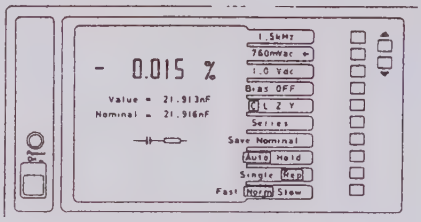


Fig. 5.4 A typical Deviation display

1 In the Deviation mode, use the C/L/Z/Y key to select the required parameter.

2 Connect the reference component (if this is a capacitor, and bias voltage is required, refer to section 5.5).

3 Set up the required frequency (see section 5.2).

4 Select, as required, Series or Parallel (see 5.13) if C or L selected in Step 1; Auto or Hold (5.15); Single or Rep (5.16); and Fast, Norm or Slow (5.17).

5 Set up the required drive level (5.3); if using Single, press Trigger; then press Save Nominal.

6 Changes in the value, as % deviation from the reference component, can now be displayed as similar components are substituted, or as the original component is subjected to changes of temperature, drive level, bias, etc.

7 If the Nominal Saved has different units from the selected measurement parameter, the display will show the error message MEAS/NOM UNITS MISMATCH.

5.19 LIMITS

As stated in 4.2, this mode allows the operator to key in upper and lower pass limits on major or minor terms, as % tolerances on a nominal value or as absolute values. A typical Limits mode display is shown in Fig. 5.5.

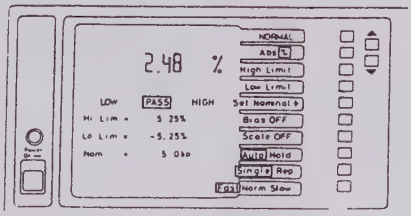


Fig. 5.5 A typical Limits mode display

Before proceeding, select NORMAL to check that the functions selected (C/L/Z/Y and D/Q/R/G) match those intended for Limits operation. (If they do not, the Analyzer will display MEAS/NOM UNITS MISMATCH). Then select Limits. The sequence is described firstly for % limits and secondly for Absolute values. The Analyzer will store limits in only one style at any time (see %/Abs Change-over).

To supplement the numerical display, an Analog Bar Display can be selected (except on a few early models). This is particularly useful when pre-set components are to be adjusted. Use of this feature is described at the end of this section.

When checking a number of similar components, the process will be quicker if Hold is used (see section 5.15).

% Limits

1 In the Limits mode, select % and High Limit.

2 Use the keypad to establish the high % figure (sign, digits and if required decimal). For example: [2] [.] [5]. (The +/- key has a toggle action and the sign can be entered before or after the digits).

3 Check the figures showing on the display. If correct, press Enter. If incorrect, press Clear and repeat step 2.

4 Select Low Limit and set up the figure in a similar manner as for the High Limit. For example: [-] [1] [.] [5].

5 Select Set Nominal and key in the required value and units. For example: [2] [1] [.] [9] [Units] [n] [F]. Check the figures showing on the display. If correct, press Enter. If incorrect, press Clear and repeat this step.

6 Check that the settings of frequency (5.2), drive level (5.3), bias (5.4), Auto/Hold (5.15), Single/Rep (5.16) and Fast/Norm/Slow (5.17) are as required.

7 Connect each component, in sequence. The display will show LOW, PASS or HIGH, together with the % departure from the nominal value (see Fig. 5.5).

Absolute Limits

1 In the Limits mode, select Abs and High Limit.

2 Use the keypad to establish the value of the high limit, pressing the digits, decimal (if required) and the Units key followed by the appropriate multiplier and units. For example: [8] [5] [.] [2] [Units] [n] [F].

3 Check the figures showing on the display. If correct, press Enter. If incorrect, press Clear and repeat step 2.

4 Select Low Limit and set up the value in the same manner as for the High Limit.

5 Check that the settings of frequency (5.2), drive level (5.3), bias (5.4), Auto/Hold (5.15), Single/Rep (5.16) and Fast/Norm/Slow (5.17) are as required.

6 Connect each component, in sequence. Readout is of the measured value, with a LOW/PASS/HIGH indication.

%/Abs Change-over

As already stated, the Analyzer stores limits in % terms or in absolute terms, but not in both at one time. However, limits entered in one set of terms can be converted by the Analyzer, automatically, to the corresponding alternative terms. When changing from % to Abs, the Analyzer establishes equivalent limits, suppressing the nominal value.

When changing from Abs to %, the Analyzer establishes a nominal midway between the two Abs limits, converting these values into symmetrical % limits.

Analog Bar Display

This function, which supplements the LOW/PASS/HIGH display of the Limits mode, in % or Abs terms, is enabled/disabled by the Scale ON/OFF soft-key. Length of the horizontal bar varies with the value of the component under test. A typical % display is shown in Fig. 5.6.

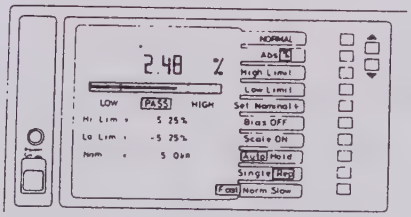


Fig. 5.6 Limits mode with Analog Bar Display

The Analog Bar Display has two fixed marks, corresponding to the High and Low limits selected for Limits mode. Whenever these limits are entered, the horizontal scaling factor is adjusted accordingly.

Scale compression is applied for values above or below the pass limits, allowing a range of values of up to 9 times the pass band to be displayed.

5.20 BINNING

When Main Index is selected, there are three Bin keys available, as outlined in section 4.2. Binning can be set up and operated in terms of % tolerances either side of a nominal value, or as absolute values. These alternatives are supported by two completely unrelated sets of stored limits (for binning only, not applicable to Deviation or Limits modes). For each of the bins 0 to 8*, when the major term is capacitance or inductance, (i.e. units of F or H), provision is made for setting also a minor term limit. This can be in terms of maximum D, minimum Q, maximum series R, minimum parallel R or maximum parallel G. In all instances, it must be set in Abs terms, whether the major term is % or Abs. The appropriate limit of maximum or minimum is applied automatically by the Analyzer.

Bin settings - major and minor terms - and the settings for normal mode measurement, can be changed at any time, but must be of the same type when Bin Sort or Bin Count is selected. Failure to observe this will result in the error message 'MEAS/BIN UNITS MISMATCH' being displayed.

Whether % or Abs binning is used, limits for each set of bins can be 'nested' or 'stacked'. Examples of each method, for % and Abs, are shown in the table. (The sets of figures are not related).

Whatever method is used to enter limits, results will be sorted by testing each bin in numerical sequence. Any bin with limits set to zero will be ignored, and rejects will be classified as bin 9.

* See end of this section for details of some early models.

Bin No.	%				Abs			
	NESTED		STACKED		NESTED		STACKED	
	High	Low	High	Low	High	Low	High	Low
0	+1%	-1%	-1%	-3%	27.5pF	26.5pF	900Ω	898Ω
1	+2%	-2%	+1%	-1%	28.0pF	26.0pF	902Ω	900Ω
2	+5%	-5%	+3%	+1%	28.5pF	25.5pF	904Ω	902Ω
3	0	0	+6%	+3%	29.0pF	25.0pF	906Ω	904Ω
4	0	0	+10%	+6%	30pF	24.0pF	0	0
5	0	0	+15%	+10%	0	0	0	0
6,7,8	0	0	0	0	0	0	0	0
9	REJECTS				REJECTS			

Note that limits for unwanted bins should be at zero.

'Nested' and 'Stacked' limits are alternatives: only one set can be stored for %, together with one set for Abs.

The 'Reset' key returns all three limits (High, Low and Minor) to zero for the selected bin. The 'Next' key is used when entering limits in order, starting with Bin 0 High Limit and stepping to the next limit or bin number in sequence.

Binning in % terms

1 From Main Index, select Bin Set.

2 Select % and Set Nominal.

3 Use the keypad to set the required digits, decimal, multiplier and units. For example: [3] [5] [0] [.] [0] [Units] [p] [F]. Check for correctness on the main display. If satisfactory, press Enter. If not correct, press Clear and re-set the required value.

4 Press High Limit. To select a particular Bin number, use the ▲ and ▼ keys. The Bin number in use is shown boxed on the main display. A typical display for setting limits in % Binning is shown in Fig. 5.7.

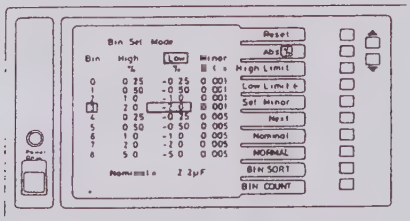


Fig. 5.7 A typical Bin Set display

5 Select Bin 0, and use the keypad to set the required high limit value, including sign if necessary. (The Analyzer will accept the sign before or after the number is keyed). No units are required when keying limits in the % mode. Check for correctness on the main display. If satisfactory, press Enter. If not correct, press Clear and re-set the required number.

6 Press 'Next'. This automatically steps the Analyzer to the next limit (i.e. Bin 0 Low) and, unless the operator makes an overriding key entry, assumes the Low Limit to be numerically the

same as the High Limit for the bin being set, but with a negative sign. If this is acceptable, again press 'Next'. If unacceptable, use the keypad as in step 5 to enter the required Low Limit and then press 'Next'. If the Nominal value set was in terms of C or L, the selection will be 'Minor' for Bin 0: perform step 7. Otherwise, go to step 8.

7 The minor term will usually be in terms of maximum D when binning capacitors, and in terms of minimum Q for inductors. However, provided that the selection corresponds with that made in the Normal mode, it can be D or Q for both C and L, or loss resistance (maximum series R or minimum parallel R) or maximum parallel G. Use the keypad to select the required number (Abs terms only, not %), then 'Units' followed by D, Q, Ω or S preceded by any necessary multiplier. Check for correctness on the main display. If satisfactory, press Enter. If not correct, press Clear and re-set the required value. If the minor term selection is not required, it can be disabled by entering a limit value of 0. The units must, however, match those selected in the Normal mode. Press 'Next'.

8 For Bin 1 High, set the limit required and continue until all relevant bins have High, Low and, when appropriate, Minor limits. Use the Reset key to clear all limits to 0 on any unused bins.

9 The setting(s) for any particular bin can be amended at any time by selecting the appropriate Bin No. and entering the new limit(s).

10 Check that the Normal settings are the same as those selected for Binning. If they are not, the message MEAS/BIN UNITS MISMATCH will appear when Bin Sort (or Bin Count) is pressed.

11 Press Bin Sort. Measurement of a component will now produce a display showing the Bin No. in which the value lies, together with measured values for the major and minor terms.

Binning in Absolute terms

1 From Main Index, select Bin Set.

2 Select Abs.

3 To select a particular Bin number, use the ▲ and ▼ keys. The Bin number in use is shown boxed on the main display.

4 Select Bin 0, High Limit, and use the keypad to set the required digits, decimal, multiplier and units. For example: [4] [7] [.] [3] [Units] [n] [F]. Check for correctness on the main display. If satisfactory, press Enter. If not correct, press Clear and re-set the required value.

5 Press 'Next'. This automatically steps the Analyzer to the next limit (i.e. Bin 0 Low). Enter the appropriate value using the keypad in the same manner as described in step 4. Press 'Next'. If the limits set for Bin 0 were C or L, the selection will be 'Minor' for Bin 0: perform step 6. Otherwise, go to step 7.

6 The minor term will usually be in terms of maximum D when binning capacitors, and in terms of minimum Q for inductors. However, provided that the selection corresponds with that made in the Normal mode, it can be D or Q for both C and L, or loss resistance (maximum series R or minimum parallel R) or maximum parallel G. Use the keypad to select the required number (Abs terms only, not %), then 'Units', followed by D, Q, Ω or S preceded by any necessary multiplier. Check for correctness on the main display. If satisfactory, press Enter. If not correct, press Clear and re-set the required value. If the minor term selection is not required it can be disabled by entering a limit value of 0. The units must, however, match those selected in the Normal mode. Press 'Next'.

7 For Bin 1 High, set the value required and continue until all relevant bins have High, Low and, when appropriate, Minor limits. Use Reset key to clear all limits to 0 on any unused bins.

8 The setting(s) for any particular bin can be amended at any time by selecting the Bin No. and entering the new limit(s).

9 Check that the Normal settings are the same as those selected for Binning. If they are not, the message MEAS/BIN UNITS MISMATCH will appear when Bin Sort (or Bin Count) is pressed.

10 Press Bin Sort. Measurement of a component will now produce a display showing the Bin No. in which the value lies, together with measured values for the major and minor terms.

Binning - Early models

Some early models of the Analyzer have Bin 0 dedicated to a single minor term limit for each of the % and Abs binning modes. Bins 1-8 have only 2 limits for each mode (High and Low - no minor term limit). In general the operation is the same as just described except that Bin 0 must be selected when setting any minor term limit. When binning, Bin 0 on early models is used when components fail the minor term check (whereas, on later models, passing the minor term check is one of the conditions for acceptance into a particular bin). Also, on early models, Bin 0 is not available for setting High or Low limits on major terms. The display and soft-key labelling is different (see Fig. 5.8).

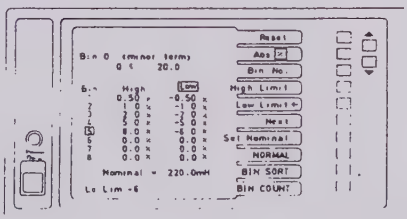


Fig. 5.8 A typical Bin Set display (Early models only)

Bin Count

This is a non-volatile data logging mode which stores the total number of measurements falling into each bin, together with the batch total. The store is up-dated only when measurements are triggered in Single mode, with either Bin Count or Bin Sort selected. With Bin Count

selected, measurement errors (misconnected components, etc) can be corrected by pressing 'Delete last'. The Analyzer requests confirmation of this by use of the Enter key. With Bin Sort selected, an error can be deleted by first changing to Bin Count, and then proceeding as above.

To clear all stores, select Bin Count, press 'Delete all', and confirm this by use of the Enter key. WARNING. This procedure resets to zero the count for all bins and the batch total.

5.21 2, 3 & 4-TERMINAL CONNECTIONS

The Analyzer has four front-panel sockets for screened cable connections to the Unknown component, test fixture or conductivity cell. In each case, the outer connection provides the screening and the inner is the 'active' connection. The innermost pair of panel connectors carry the signal source (orange) and current return (red) signals, while the outer pair serve to monitor the actual voltage at the Unknown, excluding any IR drops arising in the source and return leads. With the Kelvin Clip leads supplied, or with the alternative Component Fixture CF1005, screened four-terminal connections are made automatically to the component under test.

In some cases it may prove more convenient to use leads with crocodile clips or other special terminations. Standard leads type 1305 or 1505 are available or special leads may be manufactured locally. Any connecting leads longer than about 15 cm should be screened, and the screens of the leads connected to the Orange and Red sockets should be connected together at the component or fixture end. This connection may also be used to ground any screens or guard terminals associated with the component or fixture. It is important that the screens of the Brown and Yellow sense leads are left unconnected at the component end.

To minimize variations in lead inductance (low impedance high frequency measurements) the 4 wires should be tightly laced together, ensuring that the Red and Brown leads are diagonally opposite within the harness. If the impedance being measured is greater than about 100 ohms, 4-terminal connections are not necessary, the S/C Trim facility being used to remove the effect of series lead impedance. The Analyzer will continue to operate with the Brown and Yellow sense leads disconnected; to maintain accuracy do not plug anything into the Brown or Yellow sockets. The characteristics of cables used for special leads may affect measurement accuracy when the Unknown impedance is very low or very high, particularly with extended length cables.

For low impedances, the main advantage of 4-terminal connections is to reduce the effect of contact resistance variations at the Unknown component. Resistance of the central conductor reduces the 4-terminal performance, degradation increasing linearly with lead resistance.

After trimming with connections of 0.45 ohms/lead, resistance variations will be reduced by approximately 100 times compared with 2-terminal connections.

For measurements made on the highest impedance ranges, cable capacitance may increase measurement errors, particularly at high frequencies. A total capacitance of 500pF per cable will produce no degradation, and increasing this to 1.5nF per cable will give a maximum error of 0.1% for frequencies up to 30kHz, increasing to 1% at 300kHz. If 2-terminal connections are used, these capacitance figures may be doubled. For frequencies of 1kHz and below, or on lower measurement ranges, these errors become negligible.

If the Unknown component has a large area of metal not connected to either of its measured terminals (e.g. a screen or core), this should be separately connected to ground using the green clip lead. If on the other hand there is a relatively large unscreened conducting surface which is connected to one of its measured terminals (e.g. an air spaced tuning capacitor), this should be connected to the Orange signal source (bias +ve) lead to minimize noise pick-up.

In-circuit measurements

A component connected into a circuit can usually be measured even when the impedances of other components connected to it are comparable to or less than that of the one under test. This is possible by connecting one side of all such elements to the grounded neutral terminal of the Analyzer, as shown in Fig. 5.9. Zu is the unknown component, Zd and Zs are shunting elements, connected to ground via the green clip lead when using standard leads type 1305/1405/1505/1605.

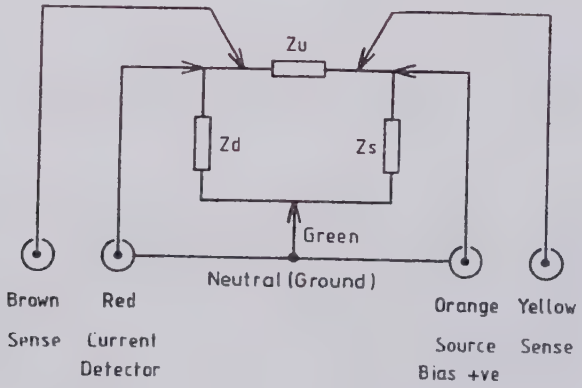
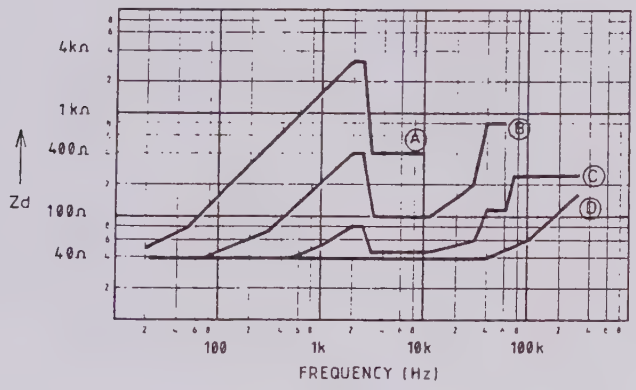


Fig. 5.9 In-circuit measurements

The presence of Zd introduces a small measurement error, dependent on the frequency and impedance range in use. Fig. 5.10 shows the minimum shunt impedance (i.e. R, ωL or 1/ωC) for an additional error (magnitude or phase) not exceeding 1%. Note that when measuring high impedances it may be beneficial to use range Hold and select a lower measurement range. (See section 5.15).



Curve	Range(s)	Level
A	8	≧ 250mV
	7	< 250mV
B	7	≧ 250mV
	6	< 250mV
C	5 & 6	≧ 250mV
	4 & 5	< 250mV
D	1 - 4	≧ 250mV
	1 - 3	< 250mV

Fig. 5.10 Effect of shunt loading on current terminal

The effect of Zs alone is negligible compared to the equivalent Zd effect, although signal level reductions could occur on ranges 1 and 2 (drive current divides between Zu and Zs). On ranges 3, 4 and 5 the signal drive voltage has a low output impedance and it is important that the total current in Zs and Zu does not exceed 125mA rms. On ranges 6, 7 and 8 the drive voltage has a source impedance of nominally 50 ohms. If the level reduction is significant, noise performance will be impaired. When Zd and Zu are connected simultaneously, an additional error term occurs due to the impedance of the guard lead. This error may become significant when Zu is larger than Zd and Zs and is given by

$$\text{Error (\%)} = 100 \times \frac{Zu \times Zg}{Zs \times Zd}$$

At low frequencies, Zg is approximately 50mΩ for leads type 1305 or 1405, or 25mΩ for leads type 1505 or 1605. At frequencies above 10kHz the series inductance, which depends to some extent on lead and component positioning, may become significant. For lowest inductance, arrange the leads in order to minimize the areas of the two loops formed by a) the Orange (Source) lead, via Zs and the Green lead to neutral and b) the Red (Current Detector) lead, via Zd and the Green lead to neutral. In this case inductance should not exceed 0.25μH.

Note that the low frequency resistance value can be significantly improved by returning Zs and Zd directly to the outer of the Red BNC connector, although this may conflict with the h.f. inductance requirement.

5.22 KEYBOARD LOCKOUT

The Analyzer has provision for protecting all key settings against unauthorized or inadvertent changes. By entering 'Code 6425' the functioning of all keys except Trigger is disabled. In this situation, the selected parameters and all measurement conditions are maintained and cannot be varied. Note that the keyboard lockout is non-volatile, i.e. it will remain locked if power is removed and restored. When any changes are required, re-entering 'Code 6425' will restore normal operation.

6 CODES

Use of the Code key, followed by one of the numbers listed below and Enter, gives access to functions which are not available via the labelled keys. (Codes 0.1 to 0.7 are test software and will not normally be required by operators. To exit from these, press Main Index.)

0.1	Character Set - Press Enter to step through.
0.2	Grid Test Pattern
0.3	Non-destructive RAM test
0.4	Keyboard test
0.5	Eprom test*
0.6	Generates 10Hz Square Wave from Analog O/P.
0.65	Tests Linearity and I/O ports on Analog O/P.
0.7	Reports if Bin Handler (SHI) is fitted.
1 to 8	Manually Set Range.
9	Display/Extinguish range number.
9.1	Clears data in non-volatile memory
10	Printer ON
11	Printer OFF
6425	Set/Reset lock on keys.

* Eprom test is slow and exit is not possible until the test is complete.

7 THEORY REFERENCE

Abbreviations

B	Susceptance (=1/X)	R	Resistance
C	Capacitance	X	Reactance
D	Dissipation factor (tan δ)	Y	Admittance (= 1/Z)
E	Voltage	Z	Impedance
G	Conductance (= 1/R)	ω	2π x frequency
I	Current		
L	Inductance	Subscript s	Series
Q	Quality (magnification) factor	Subscript p	Parallel

Formulae

$$Z = E/I \quad \text{(all terms complex)}$$

$$Y = I/E = 1/Z$$

$$Z_s = R + jX = R + j\omega L = R - j/\omega C$$

$$|Z_s| = \sqrt{(R^2 + X^2)}$$

$$|Z_p| = RX/\sqrt{(R^2 + X^2)}$$

$$Y_p = G + jB = G + j\omega C = G - j/\omega L$$

$$|Y_p| = \sqrt{(G^2 + B^2)}$$

$$|Y_s| = GB/\sqrt{(G^2 + B^2)}$$

where $X_L = \omega L$, $X_C = 1/\omega C$, $B_C = \omega C$, $B_L = 1/\omega L$.

$$Q = \omega L_s/R_s = 1/\omega C_s R_s \quad \text{(Series R,L,C values)}$$

$$Q = R_p/\omega L_p = \omega C_p R_p \quad \text{(Parallel R,L,C values)}$$

$$D = G_p/\omega C_p = \omega L_p G_p \quad \text{(Parallel G,L,C values)}$$

$$D = R_s/\omega L_s = \omega C_s R_s \quad \text{(Series R,L,C values)}$$

Note: The value Q = 1/D is constant regardless of series/parallel convention.

Series/Parallel conversions

$$R_s = R_p/(1 + Q^2) \qquad R_p = R_s(1 + Q^2)$$
$$C_s = C_p(1 + D^2) \qquad C_p = C_s/(1 + D^2)$$
$$L_s = L_p/(1 + 1/Q^2) \qquad L_p = L_s(1 + 1/Q^2)$$

The Analyzer display gives true series or parallel values (whichever format is selected) at the test frequency. It must be remembered that conversions (series/parallel), using the above formulae, will produce values applicable ONLY at the test frequency.

Polar derivations

$$R_s = |Z| \cos\theta \qquad G_p = |Y| \cos\theta$$
$$X_s = |Z| \sin\theta \qquad B_p = |Y| \sin\theta$$

Note that, by convention, +ve angle indicates an inductive impedance or capacitive admittance.

Also, if capacitance is measured as inductance, the L value will be -ve.

" inductance " " " capacitance, " C " " " "

D = tan δ where $\delta = (90 - \theta)°$ admittance measurement.

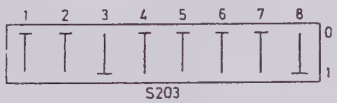
Q = 1/tan δ where $\delta = (90 - \theta)°$ impedance measurement.

8 RS232-C INTERFACE (OPTION)

When fitted with this option, the Analyzer can be used to drive a printer or other recording device conforming to EIA Standard RS232-C. The Option card, which is common to other Wayne Kerr instruments, has links and switches which have been set during installation to suit the Analyzer. Further switches must be set by the user to provide characteristics of the RS232-C link to correspond with those of the receiving equipment before data can be transmitted.

8.1 SETTING DATA CHARACTERISTICS

To gain access to the option card, first remove instrument cover. Switch S203 (located rear left) sets the characteristics of the transmitted data to match those of the printer. If the characteristics of the printer are not known, set all the switches to '1' initially. The most important characteristic, which MUST correspond at each end of the link, is the Baud rate (switches 6, 7, 8). Note that power to the instrument must be off whenever these settings are changed.



Switch 1
Sets data word length: 1 = 7 bits, 0 = 8 bits.

Switch 2
Not used.

Switch 3
Sets number of stop bits: 1 = 2 bits, 0 = 1 bit.
Setting 0 may give slight speed advantages with slow data rates.

Switch 4
Most equipments use a single parity bit to check for possible data errors. Switch 4 selects this function: 1 = ON, 0 = OFF.

Switch 5

Parity check may be odd or even: 1 = EVEN, 0 = ODD.
Note that equipments vary in their response to a detected parity error. They may print a standard character (?) or there may be a separate warning lamp. During setting up it is usually possible to run both ends of the link with parity 'off', but it should be used wherever possible to detect errors.

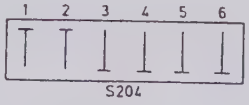
Switches 6, 7, 8

These set the Baud rate (data rate). Always use the fastest rate that the peripheral equipment can handle.

Baud rate	6	7	8
110	0	0	0
150	1	0	0
300	0	1	0
600	1	1	0
1200	0	0	1
2400	1	0	1
4800	0	1	1
9600	1	1	1

8.2 CABLE CONNECTORS & DATA FLOW DIRECTION

The RS232-C link is specified for linking peripheral equipment to computers, and some of the pin connections are different at the two ends of the cable. When driving a printer, convention dictates that the printer is peripheral, so the instrument option card should be wired as a computer. Ensure that S204 (located rear right) is set as follows:



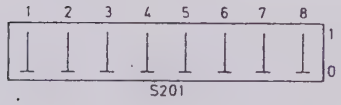
Connections to the 25-way output socket are as follows:

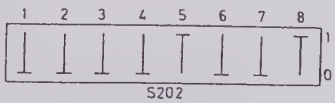
Pin	
1	Ground
2	Receive Data
3	Transmit Data
4	Clear to Send
5	Request to Send
6	Data Term Ready
7	Ground
8	Received Line Signal Det.
20	Data Set Ready

Other pins are not used for RS232-C interface.

8.3 CARD ADDRESS

Behind and to the right of SK202 are two DIL switches, S201 and S202. These set the card address and other characteristics to allow it to operate with the instrument. The correct settings for this option are shown below.





8.4 ENABLING THE PRINTER OUTPUT

When the RS232-C option is fitted, output can be enabled by entering 'Code 10' or disabled by entering 'Code 11'. When entered, the timed message 'PRINTER ON' or 'PRINTER OFF' appears, indicating the current status of the output function. Outputting data to the printer slows the measurement rate, particularly at the lower baud rates. No such slowing occurs with 'PRINTER OFF' selected.

8.5 PRINTER FORMAT

When operating in the Single mode, the instrument will generate a single printed line of up to 40 characters, terminated by CR-LF.

1.0kHz	10.98µH	0.3622 Q
800 Hz	16.00µH	0.2946 Q
600 Hz	28.06µH	0.2177 Q

The above example demonstrates the response to the measurement parameter that is being updated in Normal mode measurements. The response is similar if the parameter being changed is Level or Bias.

Status

The status of the present measurement mode (except Bin Set) is output whenever the measurement mode, measurement function or any of the measurement parameters is changed.

Freq.	Level	Bias	Fast	Auto
1.0kHz	100mA	OFF	L Q	Par

The measurement mode is Normal.

The measurement functions are L and Q.

The measurement parameters are frequency 1.0kHz, level 100mA, Bias OFF, the speed is Fast, and Parallel equivalent circuit selected.

Also the instrument is in the Auto range state.

Output of Range Error

When operating in the range Hold mode, the measurement results may or may not be suppressed when a Range Error is indicated. When there is a range error, the message 'Range Error' is output terminated with CR-LF. Any displayed results are then output on the new line, terminated with CR-LF. If no results are displayed then the output is a blank line.

```
600 Hz      -0.6nF    150.0 ohm
600 Hz      -0.4nF    150.0 ohm
Range Error
600Hz       -0.4nF    851.5 ohm
Range Error
600 Hz       0.4nF    850.0 ohm
Range Error

Range Error
```

Units Prefixes

As some printers have only upper case letters for units prefixes, the following convention is used.

F	=	femto	10^{-15}
P	=	pico	10^{-12}
N	=	nano	10^{-9}
U	=	micro	10^{-6}
M	=	milli	10^{-3}
K	=	kilo	10^{3}
MG	=	mega	10^{6}
G	=	giga	10^{9}

Printing Bin Data

When Bin Set mode is selected there are no facilities provided for making a measurement; also Bin Count has no result to output. Therefore, when the RS232-C option is fitted, a new so@ft key - Print - is labelled in Bin Count. The example below indicates the data that is output when the key is pressed. Indicated for each bin are the limits set and the number of items that had fallen into the bin. The example shows % limits with a Nominal of 500pF.

Bin	High %	Low %	Minor D < x	Count
0	0.50	-0.50	0.001	44
1	1.0	-1.0	0.001	50
2	1.5	-1.5	0.001	54
3	2.0	-2.0	0.001	50
4	2.5	-2.5	0.001	38
5	3.0	-3.0	0.001	24
6	5.0	-5.0	0.001	25
7	10.0	-10.0	0.001	17
8	20.0	-20.0	0.001	10
9			Reject	8
Nominal	500.0pF			
			Total	320

8.6 EXAMPLES

Example 1. Single measurements.

Freq	Level	Bias	Slow	Auto
600 Hz	1.00V	OFF	C R	Par
600 Hz	-0.00nF		99.950 Ohm	
600 Hz	0.02nF		99.955 Ohm	
600 Hz	-0.00nF		99.955 Ohm	

Example 2 Updating the Level parameter in Normal mode.

Freq	Level	Bias	Slow	Auto
600 Hz	1.00V	OFF	C R	Par

1.00Vac	0.10nF	99.955 Ohm
1.05Vac	0.02nF	99.950 Ohm
1.10Vac	0.04nF	99.955 Ohm

Example 3 Deviation mode with Bias On, measuring response to changing voltage:

Freq	Level	Bias	Norm	Auto
100 Hz	100mA	0 V	C	Ser
Nominal	926.8µF			

0 Vdc	0.00%	926.8µF
5.0 Vdc	0.50%	931.4µF
10.0 Vdc	2.05%	945.8µF

Example 4 Limits mode, Absolute limits

Hi Lim = 385.0 Ohm
Lo Lim = 315.0 Ohm
Slow Auto Abs Mode

330.12 Ohm	PASS
312.10 Ohm	LOW

Example 5 Limits mode, % limits

Hi Lim = 10.0 %
Lo Lim = -10.0 %
Nom = 350.0 Ohm
Slow Auto % Mode

0.0305 %	PASS
11.460 %	HIGH

Example 6 Bin Sort

Norm	Auto	Abs Mode	
Bin No. 4		0.05nF	130.92 Ohm
Bin No. 2		0.00nF	110.92 Ohm
Bin No. 3		0.05nF	120.94 Ohm

Example 7 Bin Sort with Meas/Nom units mismatch

Norm	Auto	Abs Mode
MEAS/NOM UNITS MISMATCH		
MEAS/NOM UNITS MISMATCH		
MEAS/NOM UNITS MISMATCH		
MEAS/NOM UNITS MISMATCH		

9 GENERAL PURPOSE INTERFACE BUS (GPIB) (OPTION)

When fitted with this option, the Analyzer has a GPIB interface to the IEEE Std 488-1978 (including 1980 Supplement) providing either:

i) automatic output of measurement data (e.g. to a printer), or
ii) full remote control of all functions via IEEE 488.

To permit simultaneous parallel operation of several devices on the bus, fairly complex device addressing and hand-shaking routines are necessary. These are fully defined by the IEEE Standard and a thorough understanding of them is necessary if the Analyzer is to be successfully incorporated into a system.

9.1 SETTING GPIB ADDRESS

The GPIB address and selection of talk only mode are set by SW1 on the GPIB option card.

To set the switch, the option card must be removed from the Analyzer. To do this, first disconnect the ac supply and remove the cover.

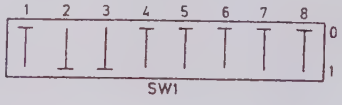
If it is desired to use the Analyzer as a talk only device, i.e. without a controller on the bus, set SW1 pole 8 to 1. The other switch poles are 'don't care'.

If it is desired to use the Analyzer with a controller:

1 Set SW1 pole 8 to 0, i.e. NOT talk only.

2 Set the required device address in binary on poles 1 to 5 of SW1 where pole 1 is the least significant bit and pole 5 is the most significant bit.

For example, with controller, device address 6:



9.2 COMMAND AND DATA FORMATS

The GPIB option conforms to IEEE Std 488-1978 (including 1980 Supplement) in the following categories of allowable sub-functions:

SH1	Source Handshake - complete capability
AH1	Acceptor Handshake - complete capability
T5	Basic Talker, Serial Poll, Talk Only, Unaddressed if MLA
TE0	No Extended Talker
L4	Basic Listener, no Listen Only, Unaddressed if MTA
LE0	No Extended Listener
SR1	Service Request
RL1	Remote/Local Function - complete capability
PP0	No Parallel Poll
DC1	Device Clear
DT1	Device Trigger - complete capability
C0	Not Controller

Also available, but not included in the IEEE 488 specification, is a sub-function which allows both Remote and Local triggering of measurements by enabling the Trigger key. This mode is selected by the LOCAL TRIGGER ON command (see section 9.3). LOCAL TRIGGER OFF inhibits this mode.

Command Format

1 The command set (see section 9.3) contains both full commands and recommended abbreviations. No other forms should be used. The full commands are designed to generate self-documenting command strings.

2 Some commands require a numeric value to follow (e.g. CODE 4; FREQUENCY 1E3). If this is omitted a command error will be reported.

3 Commands must be separated by a delimiter (;) with EOI or LF sent at the end of each command string.

4 Commands will not be implemented until EOI or LF is received. Commands will be executed strictly in the order in which they appear in the string.

5 Whilst a command string in being executed, no further commands can be accepted.

6 If a measurement is in progress when a command is received, the measurement will be aborted. The MESS? command (see Data Output, item 3) is the only exception to this rule.

7 If a command error is encountered, subsequent commands in the string will be ignored.

8 The maximum acceptable string length is 256 characters. If this is exceeded a command error will be reported.

9 A command string should contain not more than one TRIGGER command. This must be the last command in the string, otherwise a command error will be reported.

10 Upper and lower case letters will be interpreted as being the same.

11 Only commands which are normally available in the selected mode will be accepted. Otherwise a command error will be reported. For example, 'NOMINAL' cannot be selected in NORMAL mode. (Except that modes can always be directly accessed without first calling INDEX).

12 Numeric data may be integers, real numbers or exponential format. Use of non-numeric multipliers (k, p etc) is not permitted. If used, a command error will be reported.

13 Units following numeric data will be recognised by the first letter only, although the full name may be used for self documenting purposes.

14 Functions which require confirmation when selected locally do not require confirmation before execution when called via GPIB.

15 Code numbers less than 1 are reserved for self test routines. These are not available under Remote control.

16 Code 9.1 should only be sent as an individual command as it has the effect of erasing all stored data.

17 The response of the instrument to Device Clear is equivalent to the Power Up condition.

18 Typical command strings for setting the instrument might be:

a) FREQ300E3;LEVEL700E-3V;L;R;SERIES;AUTO;NORMALSPEED;TRG
b) BIN 1;HILIM 10;LOWLIM-10;NOMINAL 3E-6 FARADS;BINSORT;TRIGGER

19 If a Group Execute Trigger is sent while a command string is being processed, a measurement will not be made until the command string has been finished. A command error will prevent the trigger instruction being executed.

Command Errors

1 If a command error occurs, SRQ will be generated. Types of command error will be encoded in the Status Byte (in response to a Serial Poll). See section 9.4.

2 'Nearest Available' values will be implemented but reported as a command error.

3 When sending ac signal levels, the units (V,A) must be included. If they do not match the current machine status, a command error will be reported.

Data Output

1 Output consists of measurement results and displayed messages. The messages will be encoded as a single numeric value (see section 9.5).

2 Output comprises 4 numeric values. The first value will be the encoded messages. The remaining 3 values will be the results from measurements. These results will be sent in the order in which they appear on the screen, top to bottom.

3 The encoded messages can be output at any time, independent of the measurement status, by sending the MESS? command. In this case the three data values will be set to 0.00E00.

4 Each value will be output separately. Each will terminate with CR followed by LF with EOI.

5 All values output that are surplus to the displayed measurement mode will have the value 0.00E00.

For example, a Normal Mode measurement will give four numeric values: the encoded messages, two measured results, and a fourth value of 0.00E00.

6 Numeric results will be in Engineering Format (i.e. exponential format where exponent is a multiple of 3) with no units, of variable length corresponding to screen display.

7 If an OVERRANGE results, the value 999.9E15 will be sent.

8 At the end of any Trim sequence, the encoded message value will be output with the three data values set to 0.00E00.

9 If data is available for output when not addressed to talk, SRQ will be generated. Only one SRQ will be generated for the four data values. 'Output Data Available' is indicated in the Status Byte (in response to a Serial Poll). See section 9.4.

10 Sometimes measurement is not possible because drive levels have not been established. In this case the instrument responds by outputting the current encoded message set with the three data values set to 999.9E15.

11 If the instrument enters the listen state with any output data outstanding, then this data will be discarded.

12 If a serial poll is received when the instrument is busy, the Busy condition is indicated by the Status Byte (see section 9.4). Busy conditions include processing commands, waiting to start a measurement, measurement in progress, outputting data.

13 The result LOW PASS HIGH as displayed in LIMITS mode will be output as a decimal integer, with the following representations:

0 = Units mismatch condition
1 = LOW
2 = PASS
3 = HIGH

14 To read BIN COUNT data use the command INTERROGATE. The instrument responds by outputting the encoded messages, followed by the contents of each bin in sequence from 0 to 9, followed by the total.

Talk Only state

1 This state is selected by setting switches on the GPIB option. When in this state, output is to a 'listen always' device.

2 Data output to the printer will be formatted as detailed for the RS232-C printer option (see section 8).

9.3 COMMAND ABBREVIATIONS

The table below shows the instrument functions which are also the IEEE Commands and are fully self-documenting. The abbreviation is an acceptable short form. Either command is accepted by the instrument.

FUNCTION	ABBREVIATION
ABS	ABS
ANGLE	ANG
AUTO	AUT
BIAS ON	BSON
BIAS OFF	BSOF
BIN SET	BNSE
BIN SORT	BNSR
BIN COUNT	BNCO
BIN NO 'VALUE'	BN
BIAS 'VALUE'	BA
C	C
CODE 'VALUE'	COD
CONNECTIONS	CON
D	D
DELETE ALL	DALL
DELETE LAST	DLAS
DEVIATION	DEV
DOWN	DOW
FAST SPEED	FAS
FREQUENCY 'VALUE'	FRE
G	G
HIGH LIMIT 'VALUE'	HIL
HOLD	HOL
IAC	IAC
INTERROGATE	INT
INDEX	IND
KEYLOCK	KL
KEY UNLOCK	KU
L	L
LEVEL 'VALUE'	LEV
LIMIT 'VALUE'	LMT

FUNCTION	ABBREVIATION
LIMITS	LMS
LOCAL	LCL
LOW LIMIT 'VALUE'	LOWL
LOCAL TRIGGER ON	LTON
LOCAL TRIGGER OFF	LTOF
MESS?	M?
NEXT	NEX
NORMAL	NOR
NORMAL SPEED	NORS
PARALLEL	PAR
PRINT	PRI
Q	Q
R	R
REPEAT	REP
RESET	RES
SAVE NOMINAL	SAV
SCALE OFF	SCF
SCALE ON	SCN
SET LIMIT 'VALUE'	SLI
SET NOMINAL 'VALUE'	SNO
SINGLE	SIN
SERIES	SER
SLOW SPEED	SLO
TRIGGER	TRG
TRIM OPEN CIRCUIT	TOC
TRIM SHORT CIRCUIT	TSC
UP	UP
VAC	VAC
Y	Y
Z	Z
%	%

9.4 STATUS BYTE FORMAT

The status byte is formatted to indicate:

a) when the instrument is busy
b) when a message is displayed
c) when a result is available
d) when there is a command error

The defined bits are set according to the relevant condition or conditions.

The bit map is as follows:

X S B R M X C C

'CC' = Command error bits
'X' = not used
'M' = Message bit
'R' = Output data available
'B' = Busy bit
'S' = Service request

The command error bits indicate the following command error conditions:

00 = No error
01 = Syntax error
10 = not available
11 = buffer overflow (or DC Voltage Bias Unit not fitted)
where 0 = false, 1 = true

Examples:

01000001 = service request and command syntax error
00101000 = busy and there is a message displayed.

9.5 ENCODED MESSAGE SET

The encoded message is a decimal value, where each digit or digit pair represents messages that appear on the instrument display.

The encoded message format is as follows:

I J K K L M N

where N indicates Range or Trim errors:

0 = No message
1 = Range Error
2 = S/C Trim Error or Trim Failed:Out of Range
3 = Range Error plus S/C Trim Error
4 = O/C Trim Error or Trim Failed:Out of Range
5 = Range Error plus O/C Trim Error.

M indicates the message displayed on the warning line:

0 = No message
1 = External Bias Unit fitted
2 = Bias link not fitted

L indicates additional messages relating to the DC voltage Bias:

0 = No message
1 = Safety: bias turned off

The digit pair KK indicates the message on the message line:

00 = No message
01 = Nearest Available
02 = Voltage Drive Selected
03 = Current Drive Selected
04 = Drive Level Reduced
05 = DC Voltage Not Set
06 = (Reserved for future expansion)
07 = " " " "
08 = Meas/Bin Units Mismatch
09 = Meas/Nom Units Mismatch
10 = Level Too High
11 = (Code) Not Defined

J is reserved for future expansion

I indicates data valid or invalid or check measurement status:

0 = data valid
1 = data invalid
2 = measurement in progress

Examples:

0004002 = Drive Level Reduced and S/C Trim Error

1009005 = Data invalid plus Meas/Nom Units Mismatch
plus Range Error and O/C Trim Error.

10 STANDARD HANDLER INTERFACE (SHI) (OPTION)

10.1 INTRODUCTION

The SHI option card may be fitted into the option slot at the rear of a 6425. It will enable the instrument to measure a component, sort it into one of the eight bins according to the measurement results and then provide the signals for external bin handling hardware to physically "bin" the component. The Interface supports up to eight external bins and provision is made for external bin handler hardware to trigger a measurement directly.

Note that in this section "low" refers to a TTL logic level between 0 and 0.8V and "high" is a TTL level between 2.4 and 5V.

10.2 OPERATION

When the SHI card is fitted into an instrument, there will be no noticeable difference in its operation. If Code 0.7 is entered, the instrument will report whether or not it has detected the Interface with the messages 'BIN HANDLER FITTED' or 'BIN HANDLER NOT FITTED'. If the message 'NOT DEFINED' appears, then the software in the instrument does not support the Standard Handler Interface.

Results will be sent to the Interface only if all the following conditions are met:

i) The instrument is in Bin Count or Bin Sort mode.

ii) There is no MEAS/BIN UNITS MISMATCH error.

iii) Under Local operation, the instrument is set to Single.

10.3 INTERFACE DETAILS

The functions of the Interface lines are defined in Table 10.1. and timing waveforms are shown in Fig. 10.1. The two output signal lines $\overline{\text{BUSY}}$ and $\overline{\text{Bin Data Available (BDA)}}$ will at any time assume one of four different states:

(1) Null State

The null state is defined as

$\overline{\text{BUSY}}$ low (i.e. instrument is busy)

$\overline{\text{BDA}}$ high (i.e. no data available)

All $\overline{\text{BIN}}$ lines high (i.e. no bins selected)

This state is adopted when the instrument is unable to perform binning due to one of five reasons.

TABLE 10.1 Standard Handler Interface Signal Definitions

Pin No.	Name	Function
8	$\overline{\text{TRIGGER}}$	External trigger input. Pulling this line low while $\overline{\text{BDA}}$ is low and $\overline{\text{BUSY}}$ is high will cause the instrument to start a measurement.
10	$\overline{\text{BUSY}}$	Output signal. When low, the component at the measurement terminals of the instrument is being measured and should not be removed.
5	$\overline{\text{BDA}}$	Bin Data Available. Going low indicates the completion of a measurement cycle and that the data on the $\overline{\text{BIN}}$ lines is valid.
1	$\overline{\text{BIN 0}}$	Going low indicates a result in bin 0
2	$\overline{\text{BIN 1}}$	" " " " " " " 1
3	$\overline{\text{BIN 2}}$	" " " " " " " 2
4	$\overline{\text{BIN 3}}$	" " " " " " " 3
13	$\overline{\text{BIN 4}}$	" " " " " " " 4
14	$\overline{\text{BIN 5}}$	" " " " " " " 5
15	$\overline{\text{BIN 6}}$	" " " " " " " 6
16	$\overline{\text{BIN 7}}$	Going low indicates a result in either bin 7, 8 or 9.
24	GND	Electrical Ground.

i) The instrument is not in either Bin Sort or Bin Count mode.

ii) There is a MEAS/BIN UNITS MISMATCH error.

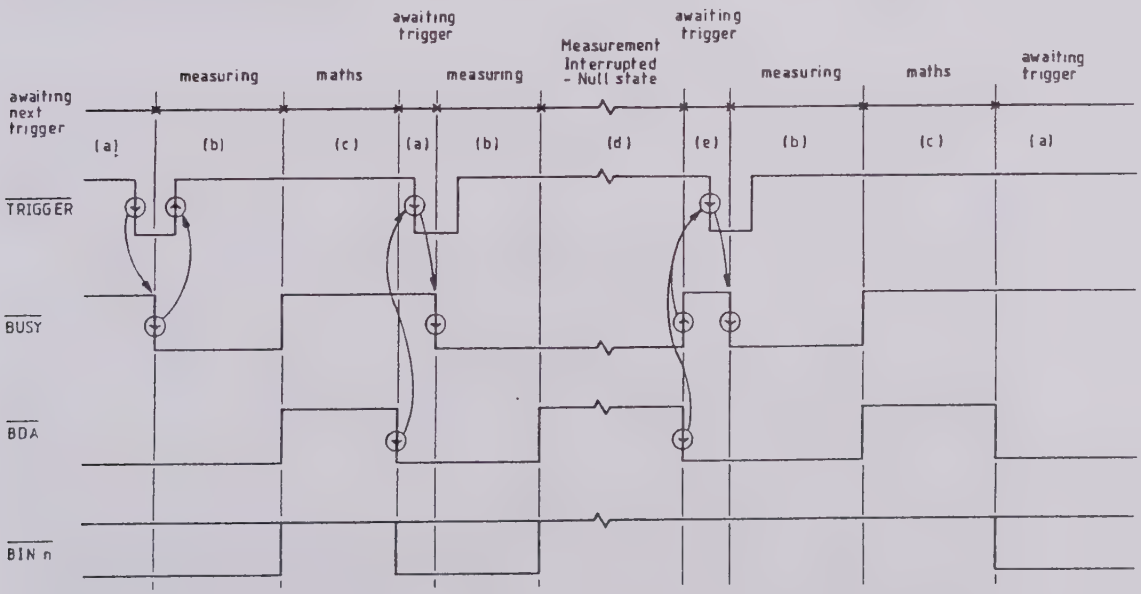
iii) The instrument is in Local operation and not in Single shot mode.

iv) The instrument has not performed a measurement since the present mode was entered.

v) A DEVICE CLEAR has been sent by a GPIB controller.

When this state is detected by external hardware, it must be assumed that the current signals on the $\overline{\text{BIN}}$ lines are invalid and should be ignored and also that the instrument is not ready for an external $\overline{\text{TRIGGER}}$ signal.

When the above conditions have cleared, the next state will be entered.



(a) - Awaiting trigger. Previous results available.

(b) - Trigger received - enter busy state. Reset trigger.

(c) - Measurement done - Remove component.

(d) - Measurement interrupted - enter 'null' state.

(e) - Null conditions have been removed - re-enter (a).

Fig. 10.1 Standard Bin Handler timing

(2) Ready for Trigger

In this state:

$\overline{\text{BUSY}}$ is high (i.e. not busy)

$\overline{\text{BDA}}$ is low (i.e. bin data is valid)

All $\overline{\text{BIN}}$ lines will be unchanged. If the previous state was a null then all bin lines will be high, meaning no bin selected, although $\overline{\text{BDA}}$ suggests that valid bin data is present.

This state indicates that the instrument is awaiting a trigger, whether from the front panel push-button, a GPIB controller or from the $\overline{\text{TRIGGER}}$ line (see section 10.4).

When the instrument receives a trigger it will respond by entering the next state.

(3) Busy

In this state:

$\overline{\text{BUSY}}$ is low (i.e. the instrument is busy)

$\overline{\text{BDA}}$ is low (i.e. bin data is valid)

All $\overline{\text{BIN}}$ lines are unchanged.

The $\overline{\text{BUSY}}$ line goes low to acknowledge the trigger and also to indicate that the component between its terminals is in the process of being measured and should not be removed until the $\overline{\text{BUSY}}$ line goes high again, when the instrument enters the next state.

(4) Not Busy

In this state:

$\overline{\text{BUSY}}$ is high (i.e. the instrument is not busy)

$\overline{\text{BDA}}$ is high (i.e. bin data is not valid)

All $\overline{\text{BIN}}$ lines high (i.e. no bins selected).

In this state the instrument has finished measuring the component under test, which may be removed and replaced by the next component. However, the instrument has still to sort the component into the relevant bin and, as the current bin is being updated, all the $\overline{\text{BIN}}$ lines are made invalid.

If this process has been completed without interruption, the instrument will re-enter the "Ready for trigger" state, waiting to measure the next component. This sequence will only be interrupted if a key on the front panel of the instrument is pressed or a command is received from a GPIB controller. In this case the current state will be "frozen" until the command has been completed. If the command results in the operating conditions of the Interface being disturbed, the instrument will enter the null state.

When the instrument is ready to continue with the next measurement, it will re-enter the "waiting for trigger" state and the measurement that was aborted may be repeated from the start.

Similarly, after the conditions leading to the null state have been rectified, another measurement may be attempted. For this to be transparent to the bin handler hardware it is recommended that it responds to the negative-going edges of the $\overline{\text{BDA}}$ line and the relevant $\overline{\text{BIN}}$ line, which will occur only when a component has been successfully measured and sorted. Note that if the component is removed, after the $\overline{\text{BUSY}}$ line goes true, and is replaced by another, then the second component will be re-measured and the first will be lost. For reliable results it is recommended that components are removed only when the instrument has completely finished sorting and has re-entered the "awaiting trigger" state. Removing the component upon BUSY going high should only be used for maximum speed, when the bin handling mechanism should be disabled before the operation of the instrument is disturbed.

Note that only 8 $\overline{\text{BIN}}$ lines are available, although 10 are provided in the software. Results indicated in bins 7, 8, and 9, will all make the $\overline{\text{BIN 7}}$ line go low.

10.4 EXTERNAL TRIGGER

Measurements may be triggered by pulling the $\overline{\text{TRIGGER}}$ line low but ONLY while the instrument is in the "awaiting trigger" state. If the $\overline{\text{TRIGGER}}$ line is pulled permanently low the $\overline{\text{BDA}}$ line will also be pulled low, impeding its operation.

If continuous measurements are required, a circuit such as that shown in Fig. 10.2 may be used to trigger a measurement from the completion of the last binning operation.

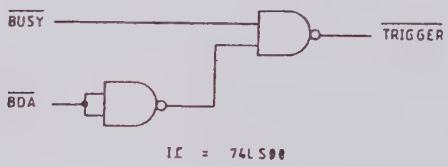


Fig. 10.2 Continuous Trigger circuit

Note that the TRIGGER line is scanned by the instrument only while in the "awaiting trigger" state and, unlike the front panel key, pulling it low at any other time will not abort a mesurement and re-start another.

Note that under certain conditions, such as when the instrument is in Hold and the components under test generate overloads, the turn-around of components being measured and sorted can reach 20 per second. If the external hardware cannot cope with this, then the next trigger should be held off until the hardware is ready.

If the external trigger is to be used under GPIB control, then local trigger must be enabled by sending the command "LTON".

10.5 HARDWARE DETAILS

Output drive levels:

Low state : < 0.5V at 48mA

High state : $\overline{\text{BIN 0}}$ to $\overline{\text{BIN 7}}$ 2.4V at -5.2mA

Other outputs, open collector.

Outputs may be used to drive external relays for isolation purposes. In this case an external relay supply not exceeding 5.0V is required, and the relay coils must be fitted with suitable shunt diodes to absorb back emf energy.

11 ANALOG OUTPUT (OPTION)

11.1 INTRODUCTION

The Analog Output option provides two analog output voltages which vary from 0 to 1 volt dc in proportion to the major and minor terms, respectively (upper and lower displayed results). These outputs can be used with a chart recorder to provide a printed copy of the variation in measured parameters with time.

The analog output voltage is calculated according to the measured result and two limits: a maximum limit corresponding to an output of 1V dc and a minimum limit equivalent to an output of 0V. These limits can be specified by the user according to the scale required. They are specified without dimensions because the analog voltage will be based upon the numerical displayed result, irrespective of its units. Therefore a maximum limit of 10 may be interpreted as 10 Henrys, 10 ohms or 10 Farads in Normal mode, or 10% in Deviation and Limits mode.

11.2 OPERATION

To enable the maximum and minimum limits to be entered, a mode called "Analog Set" is provided. If an Analog Output option card is fitted in the instrument, then "Analog Set" will be displayed in the main index and may be selected by pressing the corresponding soft-key. If the card is missing, then this key will not be labelled. Sample displays from Analog Set are given in Fig. 11.1.

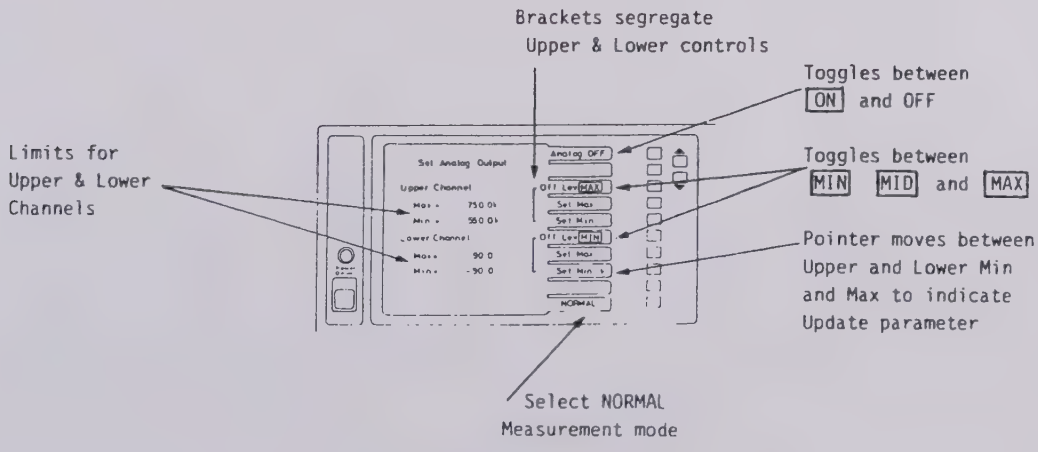


Fig. 11.1 Analog Set Mode Display

When the maximum and minimum limits have been entered, the user may switch the Analog Output to 'ON'. A measurement mode, for example "Limits", can then be entered via the Main Index. After each successive measurement, the analog voltage will be up-dated. If the result is greater than the maximum or less than the minimum, then the limiting value will be output instead.

The Analog Output will remain on until:

i) It is switched off from Analog Set mode.

ii) The Local button is pressed while in Local mode, giving this button the additional function of an "Analog Off" control.

While the Analog Output is turned off, the output voltage for each channel can be set by the user to "Min" (0V), "Mid" (0.5V) or "Max" (1.0V) to enable the deflection of the recorder to be set up.

Calculating the appropriate analog voltage slows the overall measurement rate; no such calculation will be made if the Analog Output is turned OFF.

TABLE 11.1 ANALOG SET MODE COMMANDS

SOFT KEY LABEL	FULL GPIB COMMAND	GPIB ABBREVIATION	FUNCTION
ANALOG ON/OFF	ANALOG ON *	ANN *	Enable the Analog Option.
	ANALOG OFF *	ANF *	Disable the Analog Option.
OFF LEVEL MIN/MID/MAX	UPPER OFF MIN	UFN	Specify output level when Analog is disabled for the Upper or Lower channel. MIN = 0V, MID = 0.5V, MAX = 1.0V
	LOWER OFF MIN	LFN	
	UPPER OFF MID	UFD	
	LOWER OFF MID	LFD	
	UPPER OFF MAX	UFX	
	LOWER OFF MAX	LFX	
SET MIN	UPPER MIN "Value"	UMN "Value"	Specify Minimum Limit for Upper or Lower channel.
	LOWER MIN "Value"	LMN "Value"	
SET MAX	UPPER MAX "Value"	UMX "Value"	Specify Maximum Limit for Upper or Lower channel.
	LOWER MAX "Value"	UML "Value"	

* NOTE:
These are the only GPIB Commands that may be used in modes other than Analog Set.

11.3 SOCKET DETAILS

15 pin D-type Female.

Pin 1	Analog	0V
Pin 2	Analog	Upper Output ('Major' term)
Pin 3	Analog	Lower Output ('Minor' term)
Pin 4	Digital	0V
Pin 5	Digital	O/P bit 0
Pin 6	Digital	O/P bit 1
Pin 7	Digital	O/P bit 2
Pin 8	Digital	O/P bit 3
Pin 9	Digital	0V
Pin 10	Digital	0V
Pin 11	Digital	0V
Pin 12	Digital	I/P bit 0
Pin 13	Digital	I/P bit 1
Pin 14	Digital	I/P bit 2
Pin 15	Digital	I/P bit 3

Reserved for future use

11.4 ANALOG OUTPUT

i) Output Voltage : 0 to 1V d.c. into 1 kohm minimum load. Offset adjustable by internal preset.

Output Resolution : 0.2%

Step Response : 35 ms from end of measurement to 1% final value.

Protection : Continuous short circuit.

ii) The Analog Output voltage will be calculated according to the following expression:

$$\text{Analog Voltage} = \frac{\text{Measured Value - Minimum Limit}}{\text{Maximum Limit - Minimum Limit}}$$

iii) Maximum and Minimum limits may be entered, with a sign, to enable negative percentage deviation, angles etc to be output.

The maximum and minimum limits will be interchanged automatically if the minimum limit is greater than the maximum limit. If the limits are equal, the output voltage will be OV if the measurement is lower than the limits, and 1V if greater.

iv) The upper channel output always corresponds to the upper (major term) displayed result, and similarly for the lower channel. In measurement modes with one displayed result, the upper channel only will operate.

PART 2

MP MASTER
MA20117